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THE IRON AND STEEL MAGAZINE

SUCCESSOR TO THE METALLOGRAPHIST

A MONTHLY PUBLICATION DEVOTED TO THE IRON AND STEEL INDUSTRY

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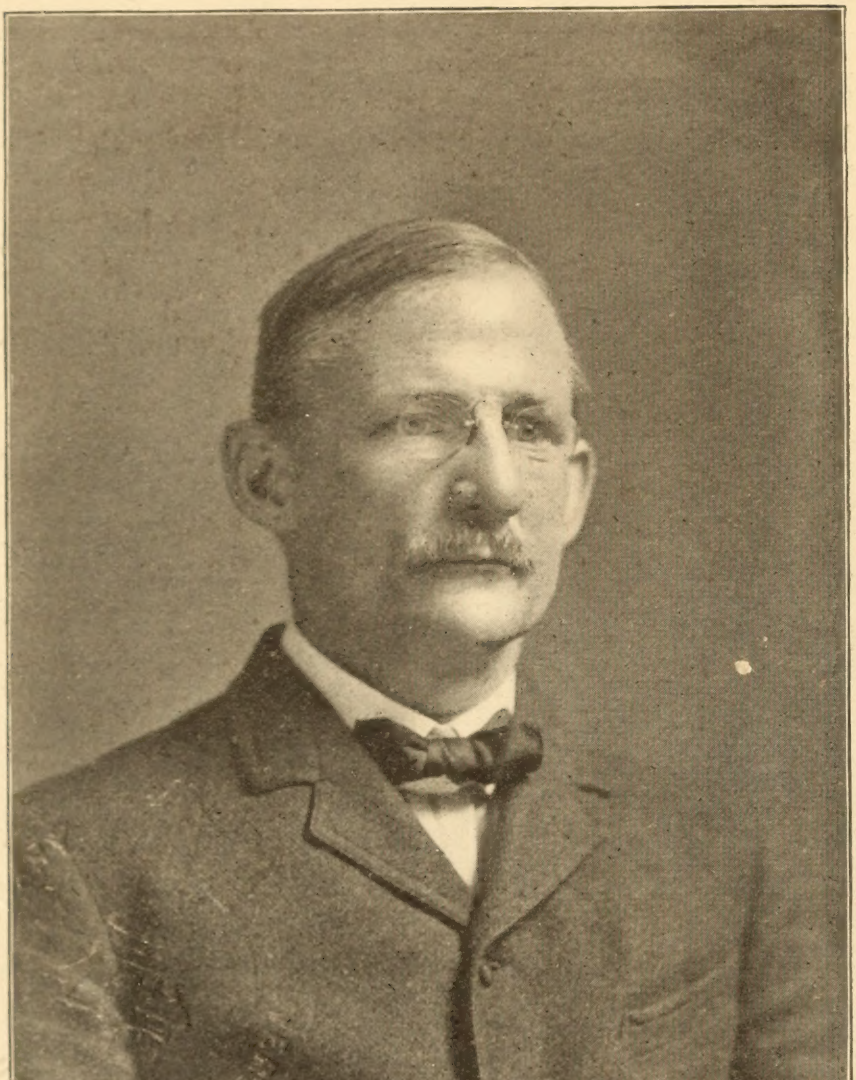


HARRY HUSE CAMPBELL

SEE PAGE 82

The Iron and Steel Magazine

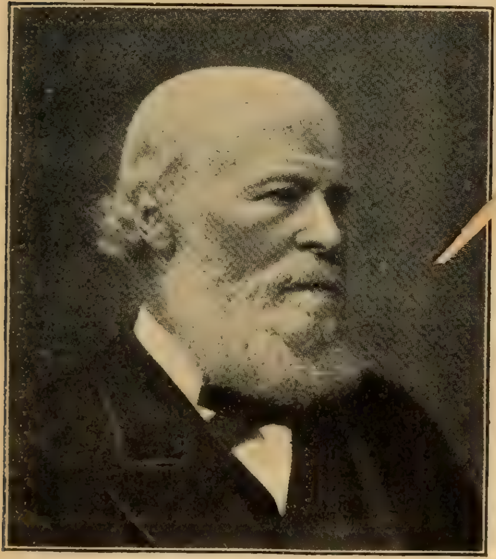
"...... *Je veux au mond publier d'une plume de fer sur un papier d'acier.*"

Vol. VIII July, 1904 No. 1

THE MANUFACTURE OF COKE IN THE HÜSSENER OVEN AT THE CLARENCE IRON WORKS, AND ITS VALUE IN THE BLAST-FURNACES*

By C. LOWTHIAN BELL
Middlesborough, England

BEFORE the year 1901, though numerous trials of coke made in different forms of patent or retort ovens had been made at Clarence, we had always come back to that made in the old beehive ovens. Every trial had proved that the dirty-looking "cinders" made in the newer apparatus were not as good as what we were accustomed to. It has been held that the black appearance of the coke was caused by its being quenched outside the coking chamber, and this certainly does account for retort coke containing, as a rule, more moisture; the recovery of the by-products has been blamed for the coke not working well in the furnace, but even retort ovens,



* The Iron and Steel Institute, May (1904) Meeting.

without this adjunct, have, in our opinion, never made coke good for the blast-furnace. I think I shall prove that, with the Hüssener oven, we can make a coke giving as good results in the furnace as that made in the beehive.

At Clarence, the coal is delivered into hoppers, whence it is taken by a traveling belt to a screen and "Carr's" disintegrator. All the coal is ground so as to pass through ⅜-inch square holes. It is then washed on a Wood & Burnet washing belt made rather longer than is usual, the water from the main belt being allowed to settle, and the silt being rewashed.

The analysis of the coal before and after washing is:

	Before	After
Ash	10.42	6.42
Sulphur	1.71	1.30
Volatile matter	28.67	29.47
Fixed carbon	59.20	62.81

These analyses are the average of the whole of the year 1903.

The highest ash dealt with has been 20 per cent, which was reduced to 9 per cent, and the coke contained 8 per cent.

During this period (52 weeks) we dealt with about 105,000 tons of coal, and the loss in washing was 10.61 per cent — taking away from the coal 4.14 per cent of its original coal. The shale, which is washed out, is continually being examined by being divided into "coal" and "shale" in a solution of a specific gravity of 1.5; 81.4 per cent is found to consist of shale containing 27.5 per cent of coal, which we think we cannot recover, and the remaining 18.6 per cent is coal with 90 per cent of coal in it, which may be considered as absolute waste, and can only be recovered at a very great cost.

The coal lost in the washing can therefore be divided into:

	Per Cent	
As coal	1.77	of the original coal
As shale	2.37	
	4.14	"

The loss as shale is attributable to the splint or stone coal found in one of the seams in Durham, the specific gravity of which prevents its being washed, so that this 2.37 per cent may be considered as unavailable.

The coke made from the washed coal contains 8.18 per cent of ash; made from unwashed coal it would contain 13.26 per cent. This extra ash, with the lime necessary to flux it, would mean 2.27 cwts. of slag more per ton of iron in the blast-furnace, and would require, to melt it, heat equal to that given by 0.35 cwts. of coke.

The coal coming from the washing belt is allowed to drain for about forty-eight hours before going to the ovens, when it contains on the average 10.60 per cent of water. This quantity of water we consider an advantage even when not compressing the coal, as it causes the coking process to be performed more slowly, making the coke harder and more dense.

It is a very difficult thing to decide which is the best form of oven for the blast-furnace manager, and I fear that our experience is that of every one else, viz., that each oven that has ever been invented is infinitely superior to the preceding ones. I do not propose to say which particular form we took for our experiments before deciding which we should adopt, but simply to say that the colliery, from which we got our coke, is situated in the county of Durham, and thus the coal treated there was similar to the coal raised at our own collieries. Sufficient retort-oven coke was brought to allow one of our furnaces to work on it alone for six or seven weeks. Samples were taken day and night, and similar samples were taken of coke from other collieries made in beehive ovens. The first series of experiments were on the volatile matter. Ten grams of coke were heated in a closed vessel, and the resulting gas was drawn off by means of a mercurial pump.

The analysis of this gas was:

Composition	Tursdale Coke Per Cent of Coke	Brancepeth	Retort Coke Per Cent of Coke
	Per Cent		Per Cent
CO_2	0.210	not taken	0.132
CO	0.136		0.508
CH_4	0.005		0.093
H	0.018		0.334
N	0.071		0.153
Total weight of gas	0.440		1.220

Experiments were then made to see the action of a regular current of CO_2 at different temperatures on coke made in various ovens. Samples (broken to the size of mustard seed) were placed in the tube of a Hoffman furnace, and through the tube were passed the wires of a Le Chatelier electric pyrometer. All air being driven off, the temperature was raised, and the resulting gas analyzed to see what proportion had been converted into CO by dissolving the carbon of the coke.

At a Temperature of from	CO in gas	CO in gas	CO in gas
Degs. F	Tursdale	Brancepeth	Retort
1500 to 1549	1	—	1
1550 " 1599	3	3.3	4
1600 " 1649	5	4.7	7.25
1650 " 1699	8	8.0	9.20
1700 " 1749	10.5	16.7	18.20
1750 and above	15.2	19.0	29.10

The extra solubility of the retort may be due to its being in the oven for a much shorter period. Beehive coke takes from 72 to 96 hours to burn, and then it is often left in the oven for ten or twelve hours before being drawn, whereas in the case of retort coke the operation is completed in about 32 hours, and as the coke-maker is generally a manufacturer of by-products, he is anxious to get the oven drawn and re-charged, more especially as the first gas is richer than the last.

In order to prove that the same action as we had observed in the laboratory took place in practice, one of the Clarence furnaces was put on to these three cokes:

	Tursdale	Brancepeth	Retort
	Tons	Tons	Tons
Iron made	3,345	5,524	4,698
	Cwts.	Cwts.	Cwts.
Coke used per ton	22.67	22.75	23.77

Burden carried per unit of coke:

	Units	Units	Units
Ore	2.116	2.095	1.738
Limestone	0.564	0.565	0.508

The analyses of the coke averaged:

	Tursdale		Brancepeth		Retort	
	Per Cent	Per Ton of Iron	Per Cent	Per Ton of Iron	Per Cent	Per Ton of Iron
		Cwts.		Cwts.		Cwts.
Moisture . . .	1.43	0.32	0.82	0.19	2.80	0.66
Ash	9.84	2.23	9.02	2.04	9.90	2.35
Sulphur. . . .	0.99	0.22	0.88	0.20	1.08	0.26
Volatile matter .	1.08	0.25	0.74	0.17	2.47	0.59
Fixed carbon. .	86.66	19.65	88.54	20.05	83.75	19.91
Total . . .	100.00	22.67	100.00	22.75	100.00	23.77

In these cases more coke made in the retort was required to make a ton of iron than was the case when using coke made in a beehive oven, and a considerable number of analyses have confirmed the opinion that the consumption of coke is increased in some proportion to the solubility of the carbon in CO_2, though we have not yet succeeded in finding the exact ratio.

Samples of the gas escaping from the top of the furnace were taken, and also samples were drawn out at the level of the tuyères when working on retort and South Brancepeth coke, in order to see if there was a greater loss in the quantity of carbon passing through the furnace in the former case than in the latter. Unfortunately, similar experiments were not made with the Tursdale coke:

Carbon per Ton of Iron at Tuyères	Retort	South Brancepeth
By calculation . .	17.43	17.21
" analysis . . .	16.15	17.33
Loss . . .	1.28, or 7.34 per cent	
Gain		0.12, or 0.7 per cent

I may say here that one of the results of these experiments has been that we now, at Clarence, take as much notice of the volatile matter in the coke we receive as we do of the ash and sulphur. This enables us to tell whether the coking process has been properly completed, and is the more necessary when using coke made in ovens producing by-products, as the coke manufacturer is very liable to draw the oven before it is, to use the

technical Durham term, "off." The system employed by Mr. Hanson in the Clarence laboratory is as follows: The coke, very finely divided, is placed in a porcelain crucible, and on to it is poured some half-dozen drops of benzine. This crucible is placed inside a larger one, and the space between the two filled with roughly-ground charcoal. The crucibles are placed just inside the muffle until the benzine takes fire and is almost entirely burnt off, when it is put into the hottest part of the muffle (a temperature of about 1,800° F.), and left for half an hour, when the inner crucible is weighed, the loss representing the volatile matter. In this way all air is driven off at a low temperature; and none of the coke itself is burnt.

A considerable number of similar experiments on coke from different ovens were made, giving results more or less the same, and we were obliged to go farther afield to find a suitable coke-oven. A visit to Germany brought to our notice the Hüssener oven working near Essen. In order to test thoroughly the capabilities of this oven, a considerable quantity of coal from the Tursdale colliery, washed and prepared for coking, was sent, and made into coke at the Hüssener works. Samples were taken of the dry coke made from Tursdale coal, and brought back to Clarence for analysis, the result being:

Ash	8.13
Sulphur	0.93
Volatile Matter	0.27
Fixed Carbon	90.67
	100.00

The volatile matter in the coke was drawn off by a pump, and was found to consist of:

CO_2	0.076	per cent of coke
CO	0.115	" "
CH_4	0.005	" "
H	0.012	" "
N	0.067	" "
Total per cent of coke by weight	0.275	

The resulting gas, on passing CO_2 over the coke, was found to contain the following quantities of CO:

PLATE I

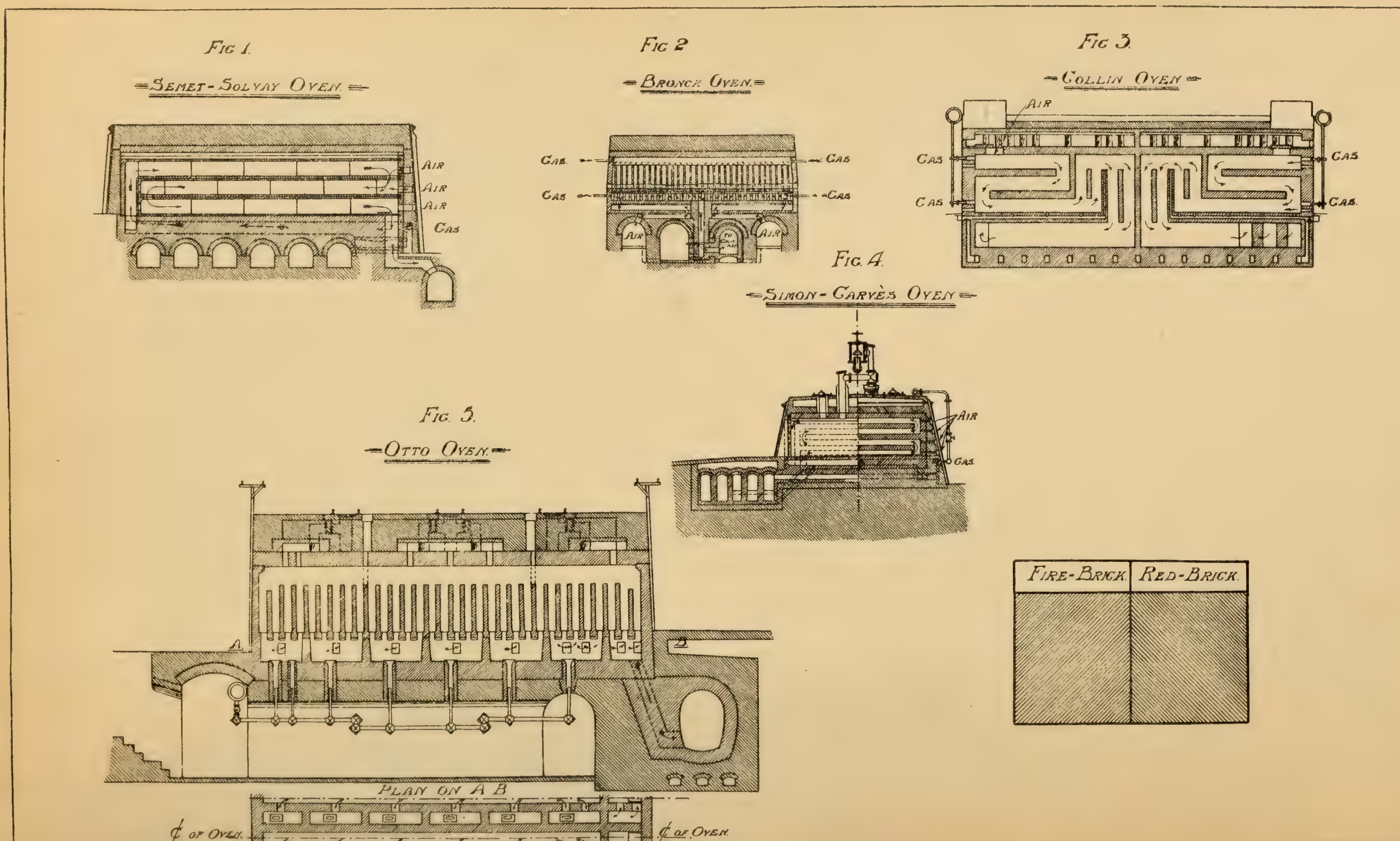


Fig 1.
Semet-Solvay Oven.
Air
Air
Air
Gas
Fig 2
Brunck Oven.
Gas.
Gas
Gas
Gas
Air
Air
Fig 3.
Collin Oven
Air
Gas
Gas
Gas
Gas.
Fig. 4.
Simon-Carvès Oven
Air
Gas
Fig. 5.
Otto Oven.
A
B
Plan on A B
℄ of Oven.
℄ of Oven.
Fire-Brick.
Red-Brick.

From 1450 to 1499° F.	. . . . . .	1 per cent
" 1500 " 1549 "	. . . . . .	2 "
" 1550 " 1599 "	. . . . . .	5 "
" 1600 " 1649 "	. . . . . .	8 "
" 1650 " 1699 "	. . . . . .	11 "
" 1700 " 1749 "	. . . . . .	15 "
Above 1750 "	. . . . . .	25 "

Both from its appearance and the results of a considerable number of similar experiments, we came to the conclusion that coke made in this particular form of oven was better for our purpose, and we decided to build sixty ovens at the Clarence works. These were started in January, 1901, and have quite borne out the opinion we had formed. As will be explained later on, we are at present doubling the plant, though three years' experience has suggested certain improvements in the size of the oven.

In order to show the difference between the Hüssener oven and others in general use, both in this country and Germany, I have reproduced sections of the following ovens on Plate I:

Fig. 1. Semet Solvay oven.
Fig. 2. Brunck.
Fig. 3. Collin.
Fig. 4. Simon Carvés.
Fig. 5. Otto.

The arrows show the direction in which the heating gas passes through the various flues, and can be compared with the similar section illustrated on Plate II, Figs. 1 and 2, of the Hüssener oven. Section AA, Plate III, is through the flues at the ram side; BB, the middle of the oven; and CC at the coke bench end. It will be noticed that between each oven there is a solid brick wall, which carries not only the top arch of the oven but also all the superstructure, leaving little or nothing to be carried by the side walls of the coking chamber. These walls can, consequently, be made very much thinner than is usual in other forms of ovens, and so allow the heat to pass more readily through them. There is, therefore, less consumption of gas for heating the coking chamber.

The horizontal divisions of the flues are built into this wall, and the bricks are dovetailed into the vertical ones, which in

PLATE II.

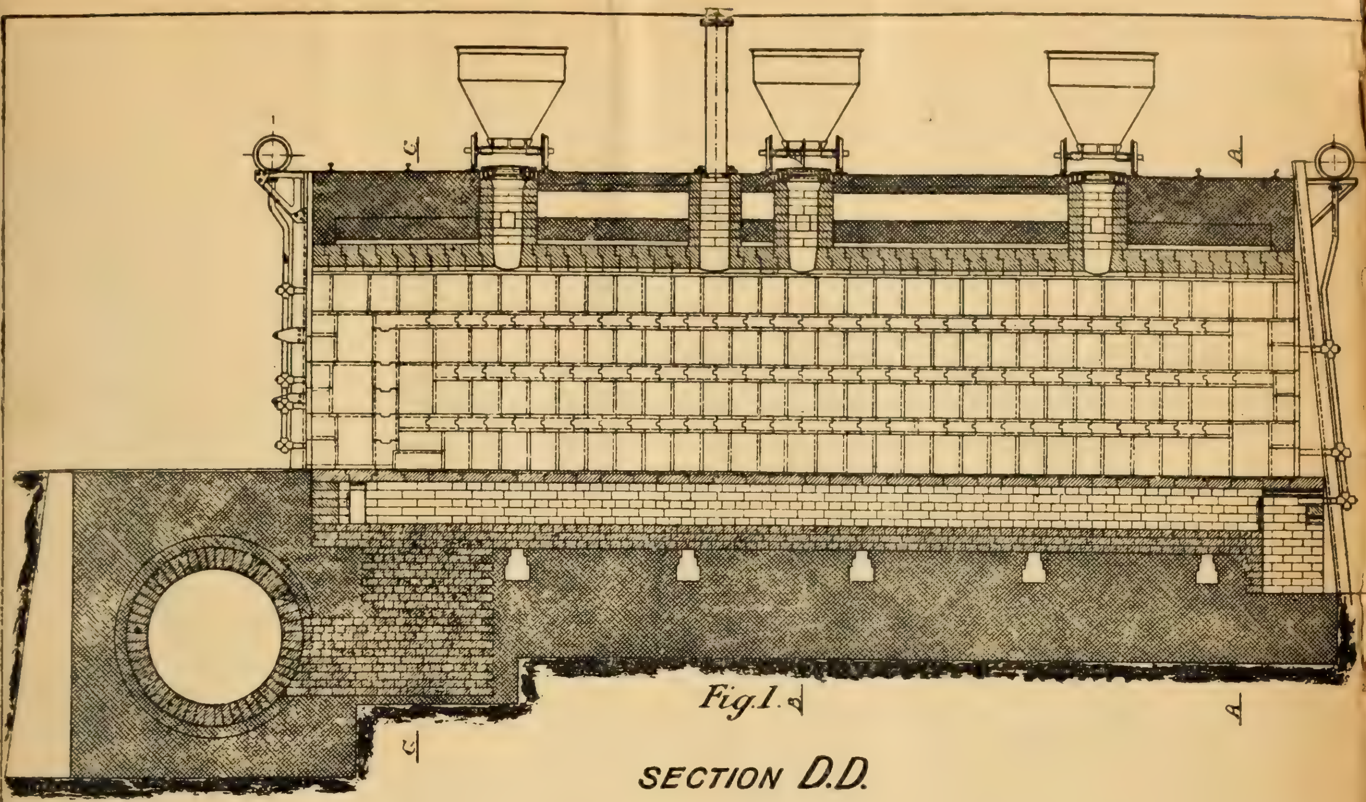


Fig. 1. A

SECTION D.D.

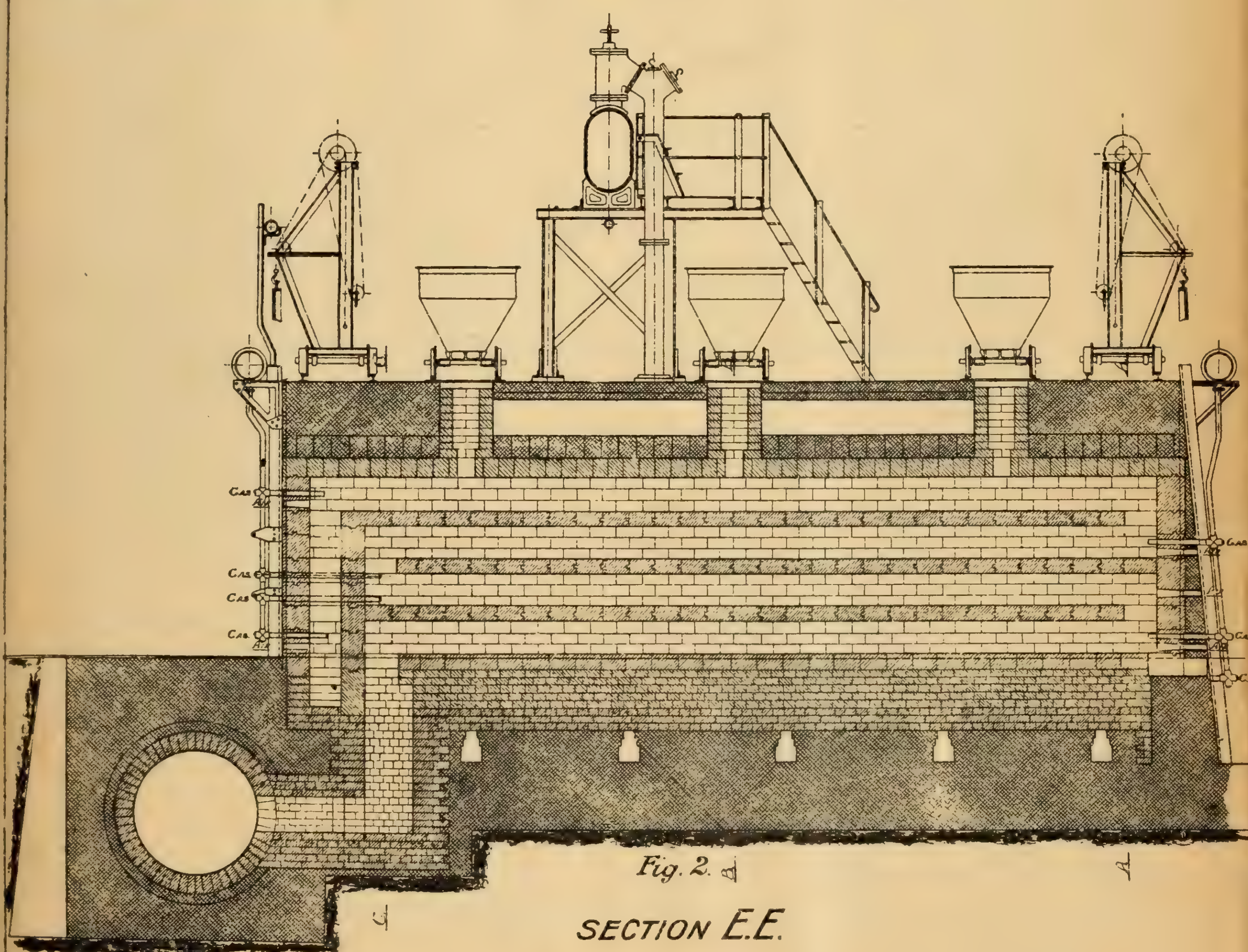


Fig. 2. A

SECTION E.E.

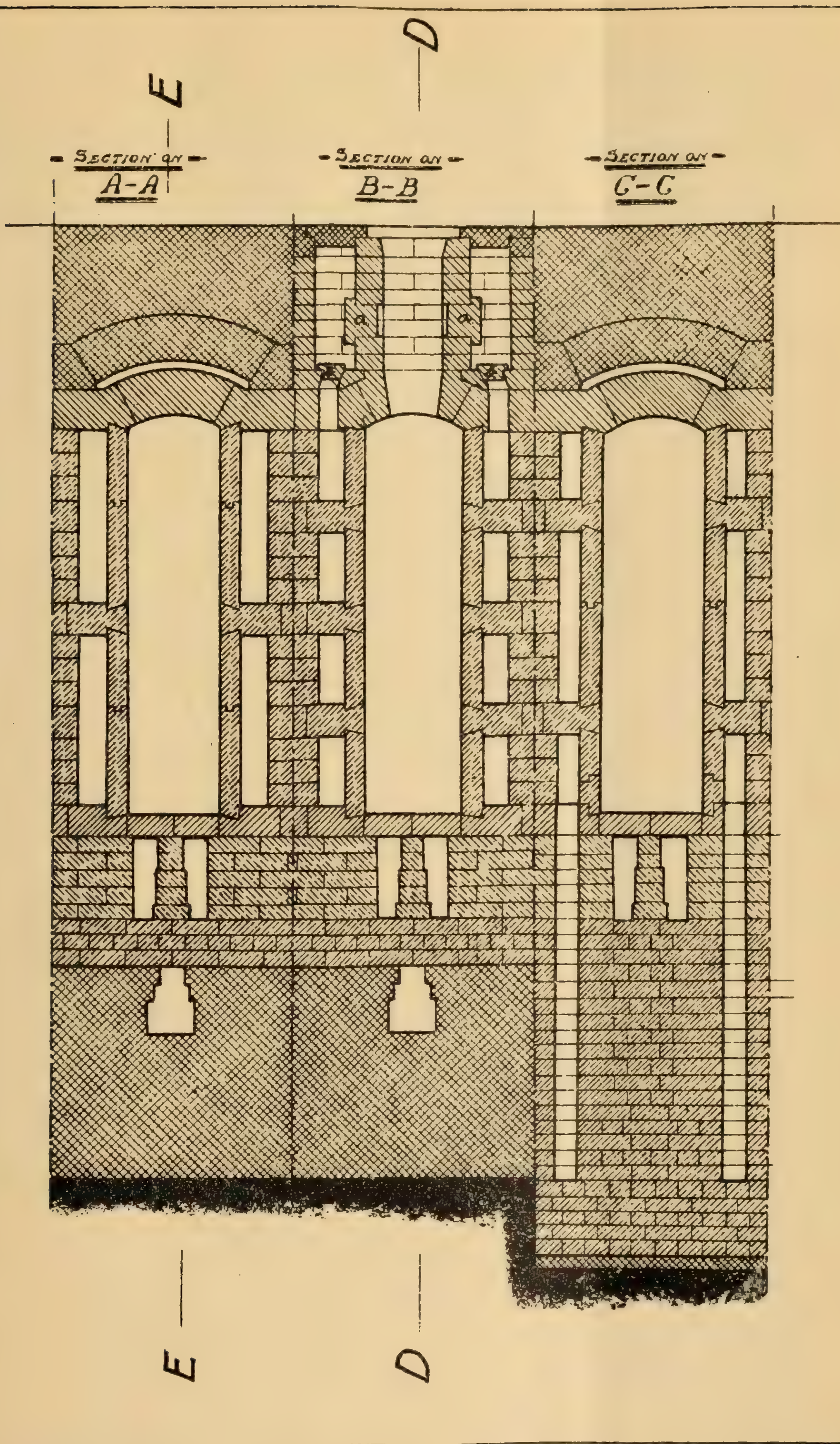
their turn are tongued and grooved. This arrangement permits any single oven to be laid off for repairs without interfering with the working of its neighbors, and also allows the vertical walls of the oven to be removed and rebuilt without disturbing the top of the oven in any way.

At the ram engine side the oven is fitted with ordinary fire doors, in order to get up heat on starting, and on each side of the charging-holes there are two loose bricks (marked *a* and *b* in the section BB.) ; by taking these out gas from the ovens is allowed to pass into the flues without going through the washing apparatus. This arrangement also permits the ovens to be used for the manufacture of coke alone, without the by-products. As soon as the oven is in work, and when making by-products, these holes are permanently bricked up. The oven has three charging-doors and one gas off-take.

In regular working, the gas coming back from the various washers, etc., enters on the ram side underneath the floor of the oven into two parallel flues, and between which is a solid brick wall. Each of these flues is connected with the upper flues of the oven, on the same side. The great advantage of this is, that the heat can be the more easily regulated on each side of the oven. The gas, having passed through the bottom flues, rises up to the top of the oven, receiving on its upward course a second, and on turning into the top flue (section C) a third supply of fresh gas. After passing back in the upper flue, the gas falls to the second one (section A), being enlivened by a fourth supply of gas, and then passes through the third flue, enlivened as before, down into the fourth (here it has been found unnecessary to admit any more gas), and so into the waste flue leading to the boilers and chimney.

It will be seen that the flues are really in two separate systems, each heating one-half of the oven, both bottom and side. All the gas is forced to pass through every part of the flue, and cannot take a short cut to the chimney. As it is enlivened in so many places, the heating of the coking chamber is very regular, and is entirely under the control of the burner. A large proportion of the air necessary to burn all the gas is admitted in the bottom flues; any further supply can easily be regulated by means of the sight-holes, which are fixed close to the inlets. About 70 per cent of the gas from the coking process

PLATE III



is used in heating the ovens, and, having done this, passes under the boilers at a temperature of about 1,500° F., raising sufficient steam, not only to work the exhausters for the ovens themselves, but also for the by-product plant, and then leaves about two-thirds of the steam available for other purposes.

At Clarence we have sufficient hot gas coming from the oven flues to work nine boilers about 30 feet long by 8 feet in diameter. The other 30 per cent of the gas is available as live gas for other purposes. One ton of coal treated in the ovens gives sufficient hot gas to evaporate about 24 cwts. of water.

Diagrams (Plate IV, Figs. 1, 2, and 3), taken by means of the Le Chatelier electric pyrometer, and photographed, are given, showing the temperatures of the gases in the side flues of the ovens — the flue going to the boilers (Plate V, Fig. 1), and so to the chimney (Fig. 2), and also of the mass of coke during the process of manufacture taken in different positions (Figs. 3 and 4). The diagram (Fig. 5), where the couple was lying on the top of the coke, shows the fall in temperature as the moisture in the coal is given off.

The average of fifteen analyses of gas coming from the ovens, after passing the condensers and ammonia scrubbers, is:

CO_2	1.2	per cent by volume
CO	3.6	" "
CH_4	31.5	" "
C_2H_4	1.5	" "
H	55.5	" "
O	0.1	" "
N	6.6	" "
	100.0	per cent by volume

Its calorific power expressed in British thermal units is 571.2 per cubic foot at 0° C. and 760 mm. Calories 143.9 per cubic foot at 0° C. and 760 mm., or 5,079.7 per cubic meter at 0° C. and 760 mm.

The gas, after it leaves the heating chambers of the ovens, consists of:

CO_2	7.9	per cent	
O	3.5	"	= 16.6 of air
N	88.6	"	
	100.00		

Fig. 1.

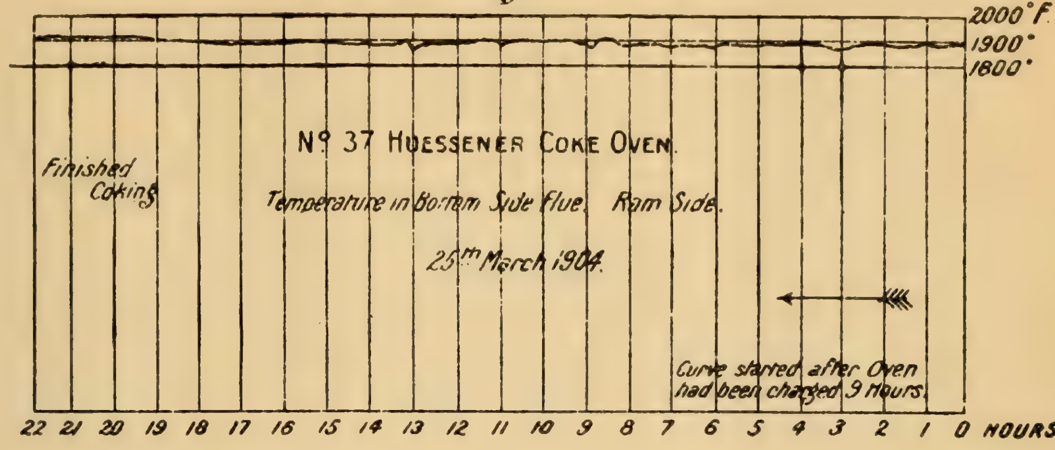


Fig. 2.

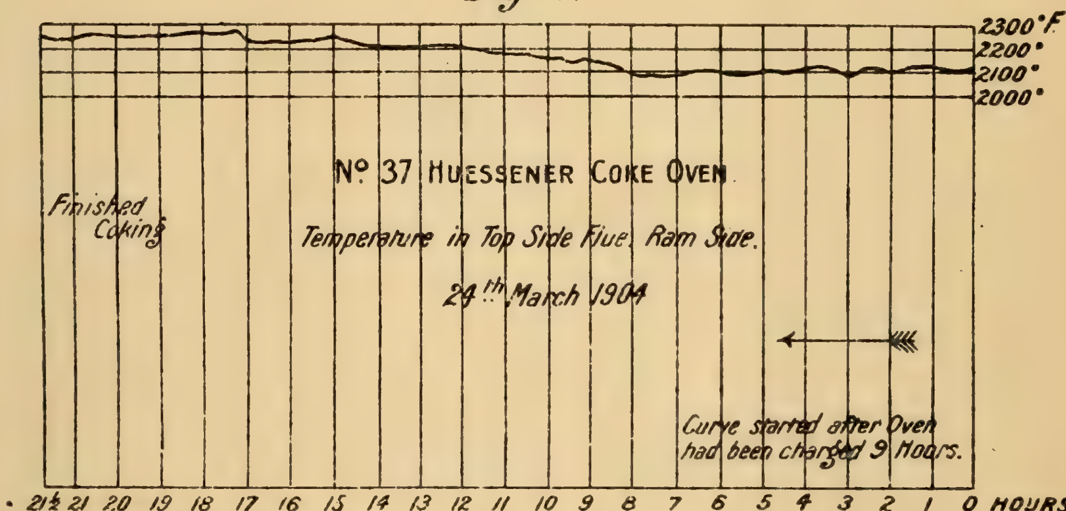
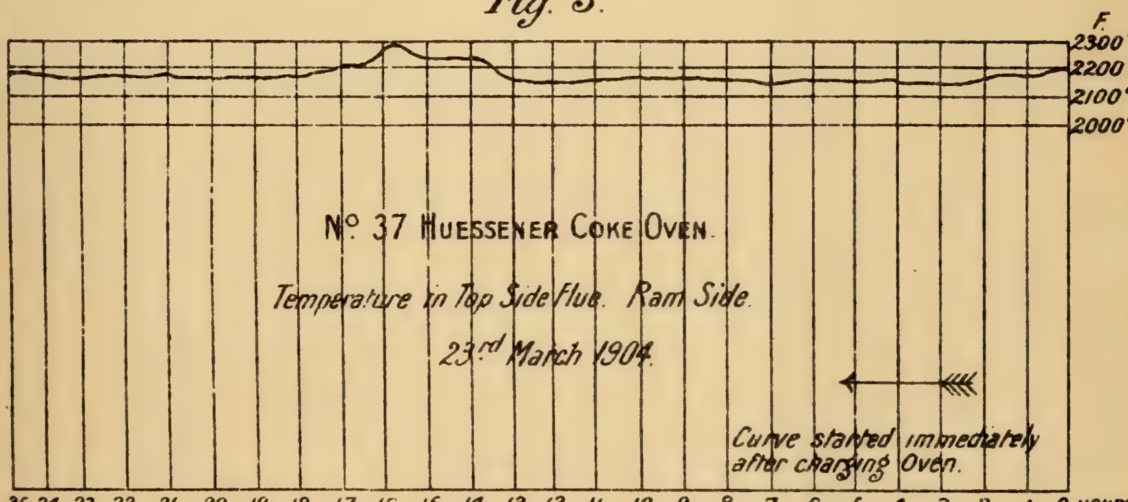


Fig. 3.



The oven which is illustrated in the Plates is not the one which we have now working at Clarence, but represents what we are at present building, which is, we consider, a great improvement. The principal difference is in the height, which is 2.100 meters to the crown of the arch, as against 1.775 meters in the present ovens. Both are 10 meters long, 0.475 meters wide at the narrow, 0.535 meters at the broad end, and 0.505 meters in the center. This new oven, which we intend to charge by means of a compressor, will, we think, make about 16 per cent more coke.

Having now explained the construction of the Hüssener oven, and the reasons which induced us to put it down at the Clarence works, I will give you the results of the working, not only of the oven itself, but also of a blast-furnace using very little coke other than that made at Clarence in the Hüssener ovens.

During the year 1903 we have treated about 105,000 tons of coal as received from the collieries, and the yield has been:

	Per Cent
Of good Blast-Furnace Coke	65.50
Breeze	2.19
	67.69

on the coal so received.

On the washed coal absolutely sent to the ovens, and considered as dry coal (i.e. less 10.60 per cent of water), the yield has been:

	Per Cent
Good Blast-Furnace Coke	72.04
Breeze	2.41
	74.45

The hardness of the coke is shown by the very small proportion of breeze, viz.:

	Per Cent
Coke	96.77
Breeze	3.23
	100.00

In order to test the hardness of different kinds of coke, we have in the laboratory a cast-iron drum, revolving at the rate

PLATE V

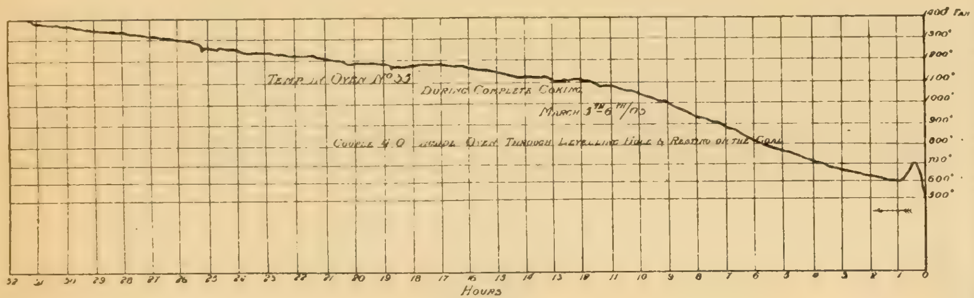


Fig 5

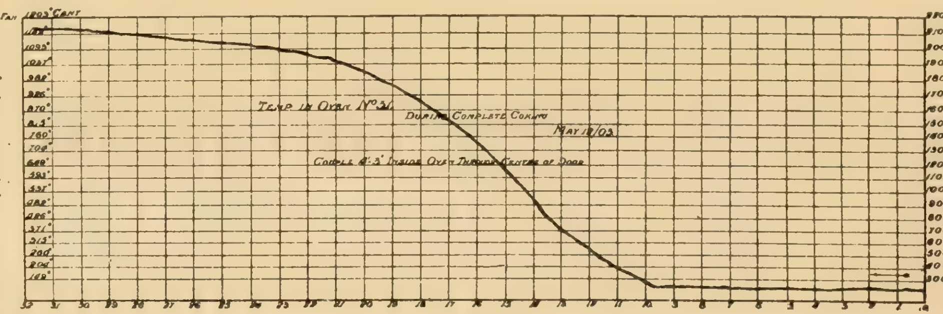


Fig 4

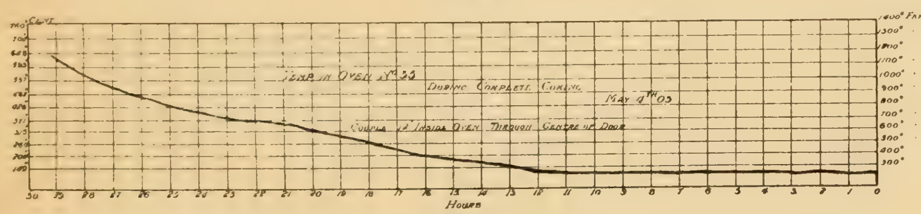


Fig 3

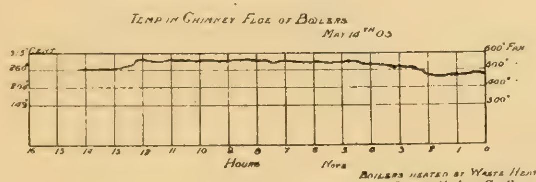


Fig. 2.

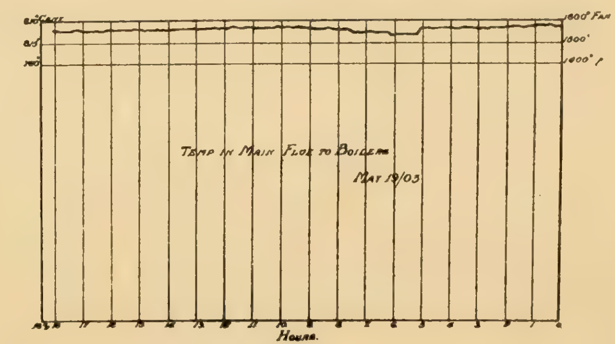


Fig. I.

of 1,000 revolutions per hour; 28 lbs. of dry coke are put in this, and the drum is revolved for one hour. The average weight of powder passing through an ⅛-inch sieve in the case of our own beehive coke is 7 per cent, and with the Hüssener coke 5.9 per cent, proving that this form of retort oven makes the harder coke.

The average analysis of the coke has been:

	Per Cent
Moisture	3.97
Ash	8.18
Sulphur	1.03
Volatile Matter	0.82
Fixed Carbon	86.00

The volatile matter in the coke drawn off by the mercurial pump consists:

CO_2	0.24 per cent of coke
CO	0.30 " "
CH_4	0.06 " "
H	0.09 " "
N	0.13 " "
Total	0.82 per cent of coke

The results of passing CO_2 over the coke was that:

From 1500	to	1549	the gas contained	1 per cent of CO
" 1550	"	1599	" "	3.5 " "
" 1600	"	1649	" "	5.0 " "
" 1650	"	1699	" "	9.0 " "
" 1700	"	1749	" "	15.0 " "
	Above	1750	" "	18.5 " "

It will be seen that the coke made at Clarence is better than that made experimentally in Germany; in fact, it is as good as that made in our beehive ovens.

The production of each oven was 21.96 tons of coal per week, each charge consisting of 5.86 tons of dry coal, giving 4.36 tons of coke. The time required for coking is thirty-two hours, and from this, each oven should have made 5.25 charges per week; in absolute work, the average was 5.21 charges.

It must be remembered that the coal contains 10½ per cent of water as it goes into the ovens. The diagram, Fig. 4, shows that for ten hours the temperature in the center of the mass of coal remains stationary at 212° F., until this water is driven off.

We are only making, as by-products, tar and sulphate of ammonia — the benzol works having only just been completed.

	Cwts.
The yield of tar has been . . .	1.06 per ton of coke
" sulphate	0.33 " "

We also make pitch, but have only done so for a short time, working up a stock which had accumulated during eighteen months. It is therefore impossible to give the yield of this product.

There is one question which is always a very serious one in the retort ovens, and that is the repairs. I have taken out the cost over the last twelve months, after the ovens had been working three years.

	Pence
Wages	0.98 per ton of coke
Stores	0.62 " "
	1.60 " "

which compares very favorably with other ovens.

After all is said, the final proof of the coke is its work in the blast-furnace, and, for this purpose, I will give the workings at Clarence for eighteen consecutive weeks, making iron entirely from Cleveland stone.

Seven furnaces, using practically all beehive coke, made an average of 780 tons of iron per week per furnace, using per ton of iron:

Coke	22.73 Cwts.
Ore	47.19 "
Limestone	12.10 "

The burden of these furnaces per unit of coke was:

Ore	2.08 Units.
Limestone	0.53 "

Of these, five furnaces get the blast from a common main. Their work was:

Make per Week, 763 Tons per Furnace

Coke used (beehive)	22.71 Cwts.
Ore used	47.41 "
Limestone	12.22 "

Burden per unit of coke:

Ore	2.09 Units
Limestone	0.54 "

The other two furnaces have separate engines, but the blowing power is not quite powerful enough. Their work is:

Make per Week, 821 *Tons per Furnace*

Coke used:

Beehive	21.92 Cwts. per Ton
Hüssener	0.83 "
Total	22.75

Ore used:

Cleveland calcined	46.62 Cwts.
Gellivare	0.09 "
Total ore	46.71 "
Limestone	11.77 "

Burden per unit of coke:

Ore	2.05 Units
Limestone	0.52 "

The furnace using practically only Hüssener coke was making a special iron, low in silicon and sulphur, which is sent direct to the open-hearth steel furnaces; this accounts for the large quantity of limestone used per ton of iron. The blast is blown by a very powerful engine, capable of working against a pressure of 20 lbs. per square inch. During the same period the working of this furnace has been:

Make per Week, 1,163 *Tons*

Coke used per ton:

Hüssener	21.45 Cwts.
Beehive	1.43 "
Total	22.88

Ore used:

Cleveland calcined	47.90 Cwts.
Gellivare	0.02 "
	47.92 "

Limestone	8.84 Cwts.
Dolomite	4.92 "
	13.76 "

The burden per unit of coke was:

Ore	2.09 Units
Limestone	0.60 "

In order to test further the working of the Hüssener coke, samples of the gas were taken over some days, when the consumption of coke was 22.44 cwts. per ton — the result being:

Carbon at the tuyères, by calculation .	16.28
" " analysis .	16.62
Gain	0.34, or 2.09 per cent

The coke is now brought from the ovens in the furnace barrows, care being taken that it should never go into the furnace hot, and, in this, we find a very great advantage — the coke being in a much better condition.

I feel I should not have done my duty to the gentlemen who have assisted me, not only in the preparation of this paper, but also in the experiments which led us to put down the Hüssener oven, if I did not express my thanks to Mr. Greville Jones, who is in charge of the Clarence furnaces, for the great attention he gave to the workings of the different furnaces, and to Mr. Weldon Hanson for the care he exercised in the analyses.

At Clarence, we think we have solved the question of retort-oven coke, and are perfectly satisfied with the results we are getting, and this is due, to a very great extent, to the way in which we have been seconded by Dr. Roelofsen, the manager of the Clarence ovens.

THE MANUFACTURE OF PIG IRON FROM BRIQUETTES AT HERRÄNG*

By HENRY LOUIS, M. A., Assoc. R. S. M.
Newcastle-on-Tyne, England

THE Herräng Mining property, now owned by the Herrängs Grufaktiebolag of Stockholm, is situated on the Baltic coast of Sweden, some sixty miles north of Stockholm, and thus about thirty miles eastward from the famous Dannemora Mines.

The total available area of ore in the larger mines has been estimated to exceed 65,000 square feet, or rather less than half that of the Dannemora mines. The ore consists of a somewhat granular magnetite with numerous accessory minerals, the most important of which are: iron pyrites, copper pyrites, zinc blende, galena, and, rarely, magnetic pyrites; of course the various minerals met with in the skarn also occur more or less abundantly distributed throughout the mass of the ore. Near the surface the ore is practically free from the sulphuretted minerals, but their proportion increases rapidly as depth is obtained. By careful hand-sorting a very high-class ore can be produced, but it may fairly be said that the ore as mined contains about 40 to 45 per cent of metallic iron existing as magnetite, and 1 to 1.5 per cent of sulphur. The phosphorus, as in all deposits of this type, is low, though rather variable; it seems to average under 0.01 per cent.

Briefly the scheme of operation is as follows: The ore as mined is conveyed from the various mines by aerial wire ropeways to the crushing works, where it is broken and crushed wet; the pulp thus produced runs to the magnetic concentrators, which take out the magnetite; the latter is conveyed by a small

* The Iron and Steel Institute, May (1904) Meeting. Abridged.

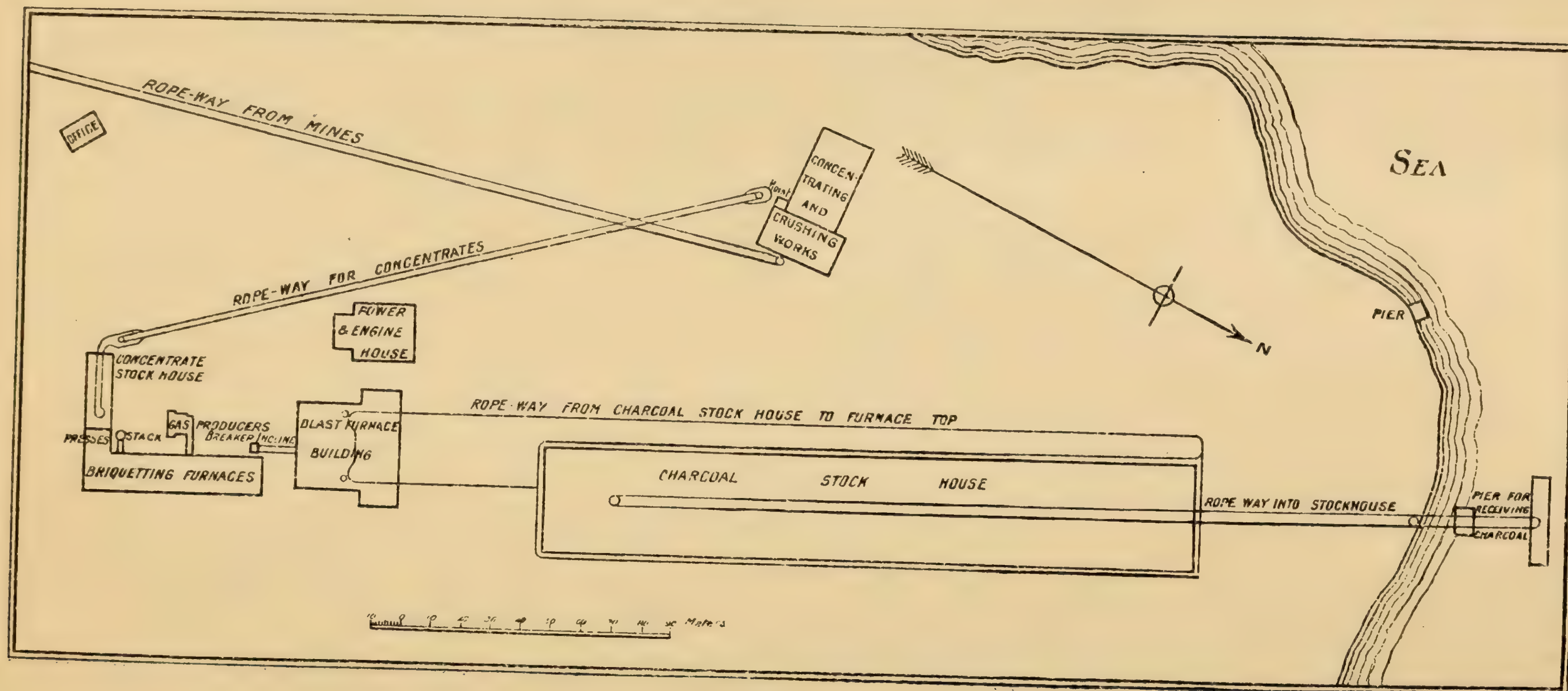

ROPE-WAY FROM MINES
OFFICE
CONCEN-TRATING AND CRUSHING WORKS
SEA
ROPE-WAY FOR CONCENTRATES
POWER & ENGINE HOUSE
PIER
N
CONCENTRATE STOCK HOUSE
PRESSES
STACK
GAS PRODUCERS
BREAKER
INCLINE
BLAST FURNACE BUILDING
BRIQUETTING FURNACES
ROPE-WAY FROM CHARCOAL STOCK HOUSE TO FURNACE TOP
CHARCOAL STOCK HOUSE
ROPE WAY INTO STOCKHOUSE
PIER FOR RECEIVING CHARCOAL
Meters

Fig. 1.

aerial ropeway to the briquetting house, where it is stamped into briquettes, which pass next through the briquetting furnace in which they are burnt; they are then hoisted up to the top of a pair of charcoal furnaces, where they are smelted for high-class pig iron; the waste gases from the blast-furnace fire the briquetting furnaces and supply gas engines which furnish the blast and also drive the dynamos of a central electrical station, from which power is conveyed to the concentrating works, as well as to the various mines for hoisting, pumping, etc.

In the concentrating works the ore is crushed and magnetically concentrated. The general arrangement of the plant is shown in Fig. 1. The ropeway from the mines delivers the ore into a large hopper, whence it passes to a large crusher of the well-known Gates pattern (No. 7), which breaks lumps of ore, as large as can be conveniently handled, down to about two inches cube. The product from this breaker is divided by means of shutes between two smaller (No. 3) breakers, which reduce the ore to about one-half inch cube. This breaking is done dry. The broken ore is caught in iron cars, which are hoisted by a platform hoist to the top of the building, where it is distributed to the feed-hoppers of four wet-crushing Gröndal ball-mills. The feeding arrangement consists of an ordinary roller feeder driven at a uniform rate and capable of accurate adjustment. The mills consist of horizontal cylinders, 40 inches in length and 80 inches in diameter (inside measurements), built up of longitudinal steel ribs, 0.33 inch deep, with cast-iron end plates, through one of which the ore is introduced together with water, escaping as pulp in a finely-ground condition through the other end plate; no screens are required. The mills are carried on rollers and driven by pinions on a long shaft gearing with a crown wheel bolted round the middle of each cylinder. Each mill is charged with about 1½ ton of balls of chilled cast iron, ranging in size from six inches diameter downwards. Experience in other Swedish concentrating works, where these Gröndal mills are extensively used, has shown that the wear of the balls amounts on the average to about two pounds of metal per ton of ore crushed. As the balls and other wearing parts will be cast at Herräng direct from the blast-furnace, and all scrap will be returned to it, the cost under this head will be trifling. The ball-mills make 30 revolutions per minute, require 20 to 25 horse-power each to drive them, and

will grind 50 tons of ore each per 24 hours. The degree of fineness of the crushed ore is regulated by the speed of the water-current sweeping through the mill.

The pulp passes to the magnetic separators, each consisting first of the magnetic slime-box and secondly of the separator proper. The capacity of this plant is fully 200 tons per twenty-four hours; the entire plant requires an electric current equal to 28 amperes at 110 volts, or say four horse-power, while less than one horse-power is required to drive the four drums. By means of this separator, concentrates with over 70 per cent of metallic iron can be produced, but in practice 63 to 65 per cent of iron is aimed at; these concentrates still, however, contain some sulphur.

The concentrates drop direct from the separator into a trough which discharges into the buckets of a ropeway that takes them to the briquetting plant.

The concentrating plant requires altogether 180 gallons of water per minute; this water is pumped from the sea by means of a rotary pump delivering into a tank; a portion of this water is caused to circulate through the water tuyères of the blast-furnace and the jackets of the gas engine, and is thus kept from freezing in the winter.

The concentrating works are driven by a three-phase motor of 150 horse-power, which supplies the whole of the motive power required; there is, however, a stand-by engine and boiler in case of any accident or break-down.

Briquetting Plant. — The concentrates are delivered by the ropeway from the magnetic separators to a store holding about 1,000 tons, where the material remains about a week, and is by that time sufficiently drained for briquetting. It is lifted by a bucket elevator to the hoppers feeding a couple of briquetting presses. These are drop presses, the plunger being lifted by a three-throw cam, so that each briquette receives three blows, the height of drop ranging from 6½ to 7½ inches, and the falling weight being 16 cwt. The briquettes measure six inches by six inches by three inches, and weigh about ten pounds. Each press makes eight to twelve briquettes per minute, there being two presses, each requiring three horse-power. The briquettes are lifted one by one off the press by a couple of men, using suitable trowels, and are placed on cars made of iron and covered with firebrick; the surface of the car measures 40 inches wide by 80

inches long, and each takes two layers of briquettes on edge, there being 84 briquettes in each tier; thus each car holds about 15 cwt. of briquettes. The loaded cars (Fig. 3) are transferred one by one to the long tunnel-shaped furnace shown in Fig. 2; it is gas fired, the combustion chamber being about one-third of the length of the furnace from the intake end. All the cars are made with a groove along one end and a projecting rib at the other, and as they are advanced by being pushed in, these fit gas-tight; the

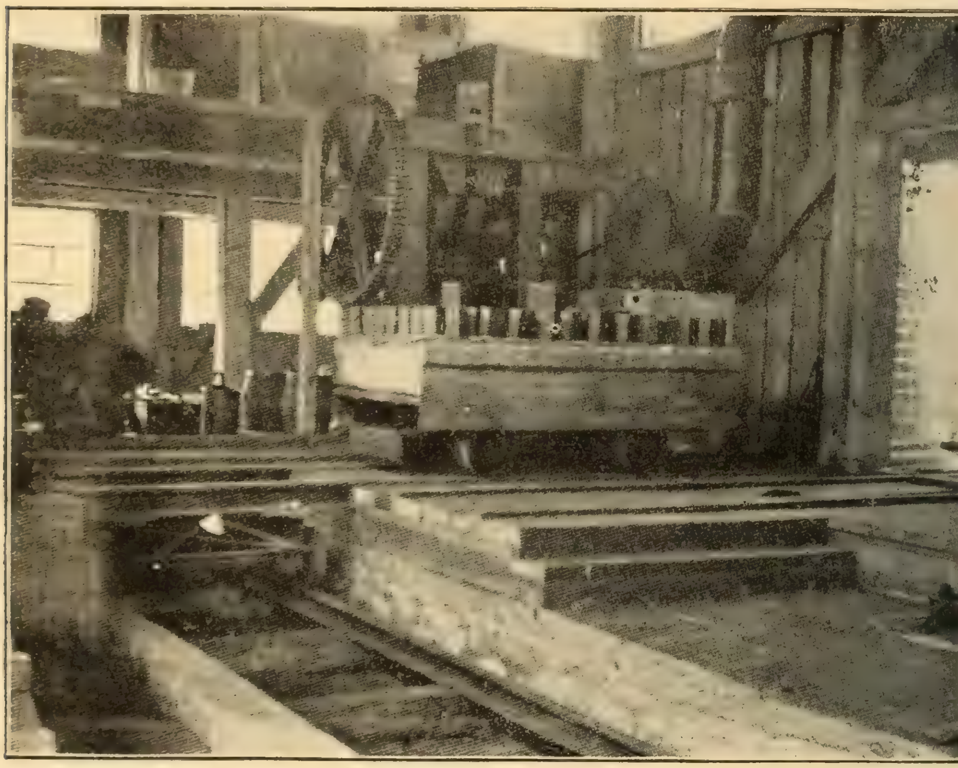
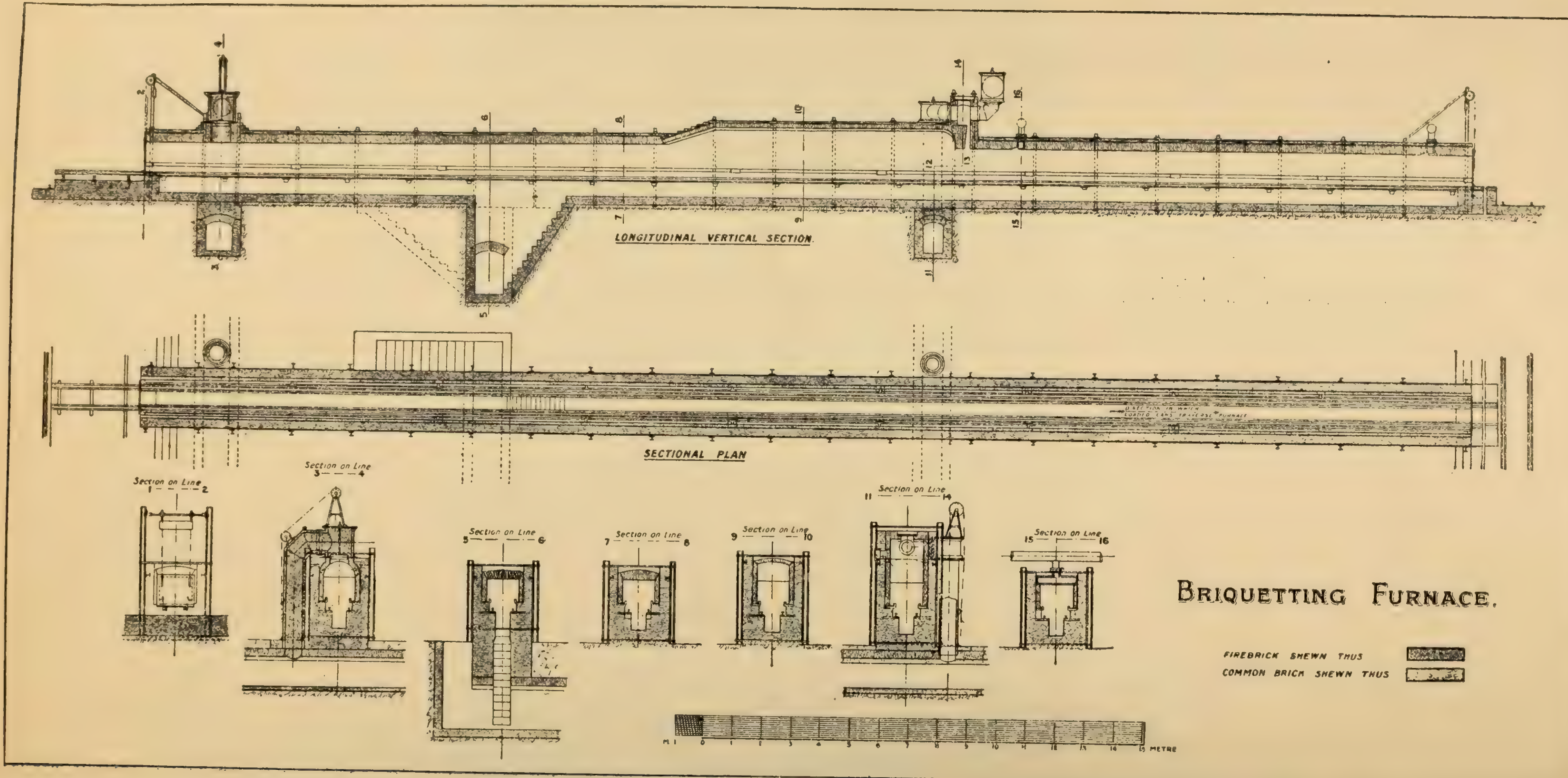


Fig. 3. Car with Briquettes.

longer sides of the cars are fitted with a deep flange, which dips into a channel kept filled with sand and running the full length of the furnace. The row of cars thus constitutes an air-tight horizontal partition, below which the air needed for combustion is admitted, thus keeping the wheels and framework of the cars cool. The wheels move in roller bearings and are lubricated with graphite, an arrangement that seems to suffer very little from the very moderate degree of heat to which it is exposed. The row of cars does not reach quite to the discharge end of the furnace, and the air current passes below the cars



LONGITUDINAL VERTICAL SECTION.
SECTIONAL PLAN
Section on Line 1 — 2
Section on Line 3 — 4
Section on Line 5 — 6
Section on Line 7 — 8
Section on Line 9 — 10
Section on Line 11 — 14
Section on Line 15 — 16
BRIQUETTING FURNACE.
FIREBRICK SHEWN THUS
COMMON BRICK SHEWN THUS
METRE

Fig. 2.

to that end and returns above them towards the combustion chamber, traversing the mass of burnt briquettes, cooling these and at the same time becoming itself heated. The products of combustion pass over the entering cars of briquettes as these advance towards the combustion chamber, thus heating these and becoming themselves so thoroughly cooled that they escape into the stack at a temperature of only about 150° C. The cars of burnt briquettes are drawn at about the same temperature, when

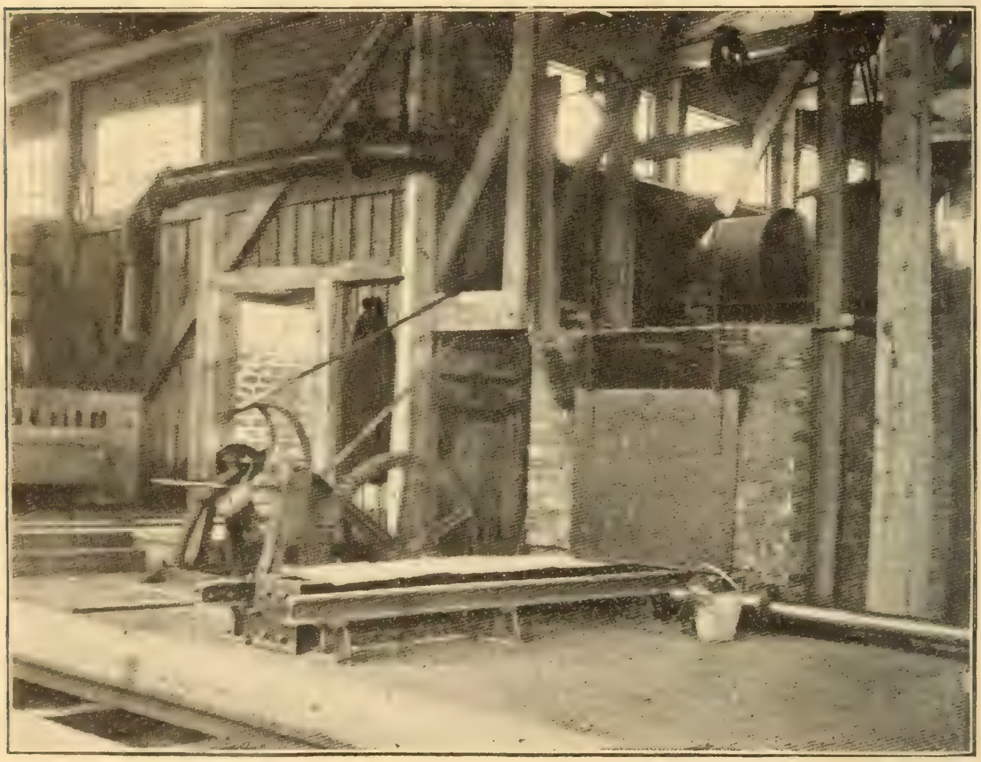


Fig. 4. Briquetting Furnace from Charging End.

a car is taken out regularly every half hour. Owing to these applications of the regenerative principle, the thermal efficiency of the furnace is very good, the chief sources of loss of heat being the evaporation of the water contained in the raw briquette (about 7.5 per cent of the weight of dry concentrates) and radiation from the furnace itself, the latter not being at all important. When fired with producer-gas, it was found that the consumption of coal in the producer amounted to 3.75 per cent of the weight of briquettes burnt. There are three of these tunnel furnaces, and their output at the above rate of working

is just over 100 tons per twenty-four hours. The temperature in the combustion chamber reaches 1,300° C., and at this heat the magnetite agglutinates sufficiently to form a firm hard briquette, which will indeed stand much rougher usage than it is exposed to at Herräng.

In addition to its mechanical action, the briquetting-furnace further acts as an exceptionally efficient calciner for removing practically the whole of the sulphur; it has already been pointed out that the concentrates retain a notable proportion of sulphur, but this is almost entirely eliminated in the briquetting process, as shown by the subjoined analysis of a briquette:

	Per Cent
Silica	7.50
Peroxide of iron	86.99
Protoxide of iron	0.55
Alumina	0.80
Oxide of manganese	0.70
Lime	3.40
Magnesia	0.20
Phosphorus	0.002
Sulphur	0.016
	100.158
Metallic iron	61.32

It will be remembered that in Swedish charcoal blast-furnace practice, in which a slag between a bi-silicate and a sesquisilicate is aimed at, the elimination of sulphur from the ore before smelting is very essential, as but little can be got rid of in a slag of this composition.

The gas for firing these furnaces is a portion of the waste gas of the blast-furnaces, being taken from the waste gas flue. In case the supply of waste gas should ever be insufficient from any cause whatever, a small battery of three gas producers of the ordinary Siemens type, with closed ashpit and a steam-jet blast, has been erected, and a supply of coal is kept at hand, ready for any emergency. The gas from these producers can also be conveyed to the gas engines in the power station, which is the more necessary since the blast-furnace blowing engines are driven by these gas engines, which need producer gas to start them. Up to the present something like 3,000 tons of briquettes have been

made by this method, and are found to work quite satisfactorily in the blast-furnace.

The briquettes are removed from the cars and stacked near the delivery end of the briquetting furnaces, close to a small Blake stone-breaker, in which they are broken into pieces of convenient size for charging into the blast-furnace. From this stone-breaker an inclined hoist takes the broken material to the charging platform of the blast-furnaces.

Blast-Furnace Plant. — An integral element of this plant is constituted by the charcoal stock house, which presents several novel features. Herräng is particularly well situated for obtaining a supply of charcoal, as the bulk of the charcoal consumed in the Swedish blast-furnaces is prepared from the slabs and other offal wood at the large sawmills situated along the shores of the Northern Baltic, both in Sweden and in Finland. For the manufacture of charcoal pig iron of the highest quality, the source from which the charcoal is obtained is not a matter of indifference; a large proportion of the timber cut up in these sawmills is floated down the rivers to the mills, and lies for a twelvemonth or more in water. It has been found that a noteworthy proportion of the phosphates contained in the wood is thereby leached out, and as this operation affects more especially the outer portions of the logs, charcoal made from sawmill slabs is lower in phosphorus than that obtained from other sources. The charcoal obtained from the Baltic sawmills appears to contain on an average 0.0068 per cent of phosphorus.

The charcoal is transported on the Baltic in large barges, carrying from 45,000 to 65,000 cubic feet of charcoal (about 220 cubic feet of charcoal weigh one ton), which are towed to their destination. At Herräng they are moored alongside of a special pier, where two barges can be unloaded simultaneously by means of light iron buckets operated by a couple of electric hoists. The buckets, of 35 cubic feet capacity, are run by a short overhead ropeway into the charcoal stock house, which is built on the shore close to the above-named pier; by this means about 14,000 cubic feet of charcoal can be transferred from the barges to the stock house in a ten-hour shift. The stock house is 750 feet long, 115 feet wide at the base, with sides sloping inwards at an angle of about 60 degrees, and 50 feet high; it is calculated to contain about 2½ million cubic feet of charcoal.

Along the botton of the stock house, on either side, are loading doors from which the charcoal is loaded into buckets, which are taken to the furnace-top by means of an inclined wire ropeway.

Limestone is obtained from the quarries of the Karta and Oaxens Quarry Company, being well known in this part of Sweden for its purity. It is delivered by sea on to the wharf at Herräng, and can thus be laid down at the furnaces at a cheap rate; on account of its high quality it is used in preference to working a poorer limestone belonging to the Herräng Company. The following is an analysis of the Oaxen limestone, furnished by the quarry company:

	Per Cent
Lime	53.74
Magnesia	0.17
Ferric oxide	0.18
Alumina	0.32
Sulphur	trace
Phosphoric acid	0.006
Silica and insoluble	3.14
Loss on ignition	42.42
Alkalies, undetermined, and loss	0.024
	100.000

There are two blast-furnaces whose sectional dimensions are 47 feet three inches in height and ten feet in diameter at the boshes, fitted with the well-known Tholander cup and cone. They are protected by the substantial stone building, customary in Sweden, and rendered necessary by the severity of the climate, the pig beds being similarly protected; the iron, as usual in Sweden, is run into iron molds. The blast is heated in Tholander pipe stoves with horizontal pipes, which are intended to maintain a blast temperature of about 250° C. Blast is furnished by a two-cylinder blowing engine, belt-driven, each cylinder being 40 inches in diameter and 40 inches stroke. Each furnace has been calculated to produce 9,000 tons of pig iron annually. As already stated, the furnace gases are conveyed by flues to the briquetting furnaces and to the gas engines of the power station, to be referred to presently, as well as to the hot-blast stoves. The charcoal consumption has been found to be exceptionally low, ranging from 140 to 160 cubic feet (or under 14 cwt.) to the ton of pig iron. The low fuel consumption required for smelting briquettes is also an important element in keeping the phos-

phorus in the pig iron produced as low as possible, the fuel being, as already indicated, the source whence much of the phosphorus is derived. The composition of the pig iron produced is as follows.

	Per Cent
Phosphorus	0.010
Sulphur	0.003 to 0.005
Manganese	0.1
Silicon	0.8 in grey pig, 0.1 in white pig

Power Station. — This is a substantial stone building containing the gas engines, dynamos and blowing engines. There are two gas engines of 225 horse-power each which drive a main line shaft. From the latter are driven the blowing engine already referred to, and two three-phase dynamos taking 175 horse-power each, as also a small continuous-current dynamo, used both as an exciter and for electric lighting purposes. The concentrating and briquetting plants have been in operation for some time, but the blast-furnaces were only blown in early this year, and have since continued to work quite satisfactorily.

Although the Herräng works are upon a small scale, yet the author ventures to submit that they embody several principles, the importance of which has only recently been recognized, but which appear nevertheless destined to play an important part in the metallurgy of iron in the near future. In the first place, the principle, long ago recognized in the metallurgy of most other metals, that injurious impurities should be eliminated from the ores at the earliest possible moment, is here sucessfully applied to iron-smelting, resulting in the production of a high-class pig iron from an ore containing very serious amounts of that troublesome impurity, sulphur, which is here eliminated before the ore goes into the furnace instead of being got rid of at a later stage. Secondly, the possibility of the successful removal of impurities by mechanical means is here illustrated. Hitherto the elimination of the impurities of iron ores — mainly silica, sulphur and phosphorus — has generally been performed by chemical means, this removal being to a great extent conducted simultaneously with the smelting operation proper, or the reduction of the oxide of iron to the metallic state. It can of course only be applied to those ores which contain their impurities in a state of mechanical admixture, and is useless for those in

which the impurities are chemically combined with the oxide of iron. Even in cases where such removal of impurities is technically possible or even advantageous, it does not always follow that it must be the commercially superior method; seeing, however, that chemical elimination can only be performed at the expense of fuel in the blast-furnace, and that the tendency of the price of fuel suitable for blast-furnace purposes is to rise, whilst in this country, at any rate, it has steadily been deteriorating in quality, and that, at the same time, improvements in the generation of power enable mechanical methods to be cheapened, it may fairly be inferred that the mechanical elimination of impurities is likely to be more advantageous economically in the future than it has been in the past. Lastly, Herräng affords one of the first examples of the employment of power, generated from the waste gases of the blast-furnace, for the purpose of mining the ore smelted in that furnace. This principle appears to be economically quite sound, and its extended application may ultimately result in a re-shifting of the centers of the iron industry; originally, of course, these were situated in iron-mining regions, and were gradually removed to the coal fields, as fossil fuel took the place of charcoal, and as the use of coal in working up the crude products of iron smelting assumed greater importance, until to-day the great centers of iron manufacture are everywhere situated upon or close to important coal fields. If, however, it is found that power, which may

Appendix No. I — *Analysis of Hand-Picked Ores*

	Glitter Mine	Kärr Mine	Kärr Mine	Eknaes Mine	Mark-dials Mine	Nyby Mine	Rya Mine	Adolfs Mine
Fe_2O_3 .	74.38	71.27	82.03	82.03	82.85	93.22	75.80	77.80
FeO . .	1.70	3.71	2.71	5.16	1.30	—	2.71	0.27
MnO . .	0.69	0.65	0.45	0.45	0.24	0.38	0.34	0.11
CaO . .	6.45	6.65	2.70	2.02	1.25	0.85	3.15	2.36
MgO . .	3.13	3.27	2.21	2.19	2.03	0.60	4.23	0.62
AlO . .	0.85	0.33	0.78	1.00	0.80	0.75	0.50	1.18
SiO . .	12.55	13.55	8.60	7.20	11.40	3.60	13.15	17.00
PO . . .	0.009	0.006	0.002	0.005	0.007	0.016	0.004	0.021
S	0.3000	0.308	0.354	0.149	0.010	0.317	0.014	0.030
Total	100.059	99.744	99.836	100.204	99.887	99.733	99.898	99.391
Fe . . .	55.17	54.20	61.81	65.60	63.00	60.90	67.50	56.80
P	0.004	0.003	0.001	0.002	0.003	0.007	0.002	0.009

fairly be considered as one of the by-products of iron smelting, can be advantageously utilized in mining iron ore, there would appear to be at any rate a possibility that smelting works may in some cases return to the ore-producing regions, and that it may once again be found to be more economical to take the fuel to the ore, the former acting now in the double capacity of source of power as well as smelting agent.

THE INFLUENCE OF VARYING CASTING TEMPERATURE ON THE PROPERTIES OF STEEL AND IRON CASTINGS*

By PERCY LONGMUIR
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Cast and Malleable Cast Iron. — Preliminary experiments with various types of cast iron conclusively proved the susceptibility of this metal to the influence of casting temperature. Commencing with an extremely hot metal, the tenacity of the cold bars gradually rises as the temperature falls until the "fair" heat is reached, a further fall in casting temperature being accompanied by a corresponding decrease in tenacity. Composition in each series remains constant, the varying properties of metal from one crucible or one ladle is in all probability due to the influence of casting temperature on the intercrystalline cohesion. In the case of white iron this influence survives the annealing process as followed for the production of malleable cast iron.

In no experiment undertaken has the influence of varying casting temperature failed to show, and none of the forms of after treatment adopted have brought the metal to a uniform level. Owing to this agreement over a wide range of composition this section has been condensed. Results obtained from a typical white and gray cast iron are embodied in Table I.

It will be noted that numbers 34, 35, and 36, all poured from one crucible, yield tenacities of 10.7, 15.9, and 12.1 tons

* The Iron and Steel Institute, May (1904) Meeting. Abridged.

per square inch respectively. Companion bars, after undergoing a treatment involving decomposition of one of the chief constituents, and a complete rearrangement of the structure still exhibit a variation forcibly shown in tenacities of 20.6, 29.2, and 26.5 tons per square inch.

The gray iron is also noteworthy. An examination of Nos. 37 to 39 show that a fall in temperature of 50° C. raises the maximum stress 4.4 tons, whilst a further fall of 105° C. lowers it 3.5 tons. The quenching experiments in this case are negative results included only for their general interest. As anticipated, the bars were finely fissured, and apparently some portion of the free carbon had entered into combination with the iron. Nos. 43 and 44 represent a type of unsound composition poured at a "high" and "fair" casting heat, both sets of bars being equally unsound. In spite of this equal unsoundness the tenacities show a difference of 2.7 tons per square inch in favor of the fair heat, and a distance apart is still maintained on subsequent treatment.

These results, confirmed by the preliminary work, sufficiently show the importance of casting temperature in the case of cast iron. The chief object of this research is, however, to show its direct bearing on foundry practice, and it was desired to ascertain if this influence holds good in all cases, irrespective of (1) composition, or (2) size of the castings. Work is now progressing in this direction; and the first series of results are embodied in Table II. These bars, 16 inches long by 0.5 inches diameter, were selected in order to determine if the relatively rapid solidification minimized the effect of varying casting temperature. The plan followed was to secure three sets of three bars each at three distinct temperatures from one crucible. One bar of each set was tested as cast, and the remaining two after treatment. The influence of casting temperature is well shown, but on the whole the results are low, owing to the small diameter and long length of the bar under test.

Steel Castings. — Only sound bars are here considered, and casting temperature is for the present studied solely in its relationship to the mechanical properties. At the outset, it is well to state that mild steels are not readily overheated in the crucible furnace, and no telling example of excessive casting temperature has been obtained from mild crucible steel. Good examples

TABLE I.—*Showing the Influence of Varying Casting Temperature on the Properties of Cast Iron*

No.	Analysis.						Casting Temperature.	Condition.	Mechanical Properties.		
	CC.	Gr.	Si.	Mn.	S.	P.			Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Elongation per cent. on 2 in.
34	3·4	...	0·39	0·05	0·02	0·02	1320° C.	As cast	...	10·7	...
35	,,	...	,,	,,	,,	,,	1230° C.	,,	...	15·9	...
36	,,	...	,,	,,	,,	,,	1120° C.	,,	...	12·1	.
34HT	0·77	2·57 †	,,	,,	,,	,,	1320° C.	Heated to 1000° C. and slowly cooled	...	18·6	...
35HT	,,	,,	,,	,,	,,	,,	1230° C.		...	24·0	...
36HT	,,	,,	,,	,,	,,	,,	1120° C.		...	21·6	.
34A	0·2 to 0·5 *	3·2	,,	,,	,,	,,	1320° C.	Annealed 100 hours in ore	20·0	20·6	1·0
35A	,,	,,	,,	,,	,,	,,	1230° C.	,, ,, ,,	24·3	29·2	3·5
36A	,,	,,	,,	,,	,,	,,	1120° C.	,, ,, ,,	22·5	26·5	2·0
37	0·52	3·4	1·78	0·28	0·04	0·27	1400° C.	As cast	...	9·7	...
38	,,	,,	,,	,,	,,	,,	1350° C.	,,	...	14·1	...
39	,,	,,	,,	,,	,,	,,	1245° C	,,	.	10·6	...
37HT	Not esti	mated	,,	,,	,,	,,	1400° C.	Heated to 940° C. and cooled in air	...	7·1	...
38HT	,,	,,	,,	,,	,,	,,	1350° C.		...	9·9	...
39HT	,,	,,	,,	,,	,,	,,	1245° C		...	8·5	...
37A	Not esti	mated	,,	,,	,,	,,	1400° C.	Annealed for 48 hours in a Clinch Jones muffle	...	6·5	...
38A	,,	,,	,,	,,	,,	,,	1350° C.		...	7·2	...
39A	,,	,,	,,	,,	,,	,,	1245° C.		...	2·6 ‡	...
37Q	Not esti	mated	,,	,,	,,	,,	1400° C.	Heated to 940° C. and quenched in water	...	2·5	...
38Q	,,	,,	,,	,,	,,	,,	1350° C		...	3·0	...
39Q	,,	,,	,,	,,	,,	,,	1245° C.		...	2·7	...
43	3·35	...	0·03	0·03	0·02	0·02	1440° C.	As cast	...	9·4	...
44	,,	...	,,	,,	,,	,,	1299° C.	,,	...	12·1	...
43HT	Not esti	mated	,,	,,	,,	,,	1440° C.	Heated to 1000° C. and cooled in air	...	13·3	...
44HT	,,	,,	,,	,,	,,	,,	1299° C.		...	17·2	...
43A	Not esti	mated	,,	,,	,,	,,	1440° C.	Heated to 1000° C. and cooled in muffle	...	18·8	...
44A	,,	,,	,,	,,	,,	,,	1299° C.		...	20·5	...

* Varies according to proximity of drillings to outside or centre of bars, from 0 to 0·2 and 0·5.

† Results obtained from average drillings. ‡ Flaw.

of "scalded" tool steel have been obtained, and with mild castings the low temperatures have yielded important results.

Recognizing the difficulty of producing typical high casting temperatures, Messrs. D. Rennie & Co., Camlachie Steel Foundry, Glasgow, kindly placed a two-ton Robert Converter at the service of this research. Mr. D. Rennie, Jr., and Mr. G. Rennie entered heartily into the matter, furnishing the author with unlimited material of known casting conditions. Special blows have been conducted, and several series of castings representing various casting temperatures obtained. All other conditions are equal, and each series of annealed bars received exactly the same treatment. Careful analytical examination has, as yet detected no change in composition in any one series, due to variation in casting temperature.

The author would here tender Messrs. Rennie his most cordial thanks for their interest in the matter, for their favor in supplying several series of bars, and above all, for independently confirming many of the results.

The results embodied in Table III show clearly the influence of varying casting temperature on steels that have been initially overheated. It will be noted that one of the series of this table is abnormally high in sulphur. This experiment was specially conducted to ascertain the influence of varying casting temperature on the properties of a mild steel comparatively low in manganese and fairly high in sulphur. An examination of Nos. 90, 91, 92, and 93 is not without interest, the influence of casting temperature is distinctly shown on the tenacities both in the cast and annealed condition. The bending angles of the annealed bars were 75°, 120°, 80°, and 70° respectively, and from steels of low extensibility these bending angles are comparatively high.

The remaining steels of Table III are normal as far as composition is concerned, and attention is drawn to the elongations and contraction of areas. As these results show, the influence of casting temperature is not removed by annealing. The fact that extensions starting from 9.5, rising to 24.0, and falling to 8.0 per cent may be obtained from one cast with metal in precisely the same condition other than casting temperature is of high practical importance. Nos. 84 to 86 cast at selected temperatures from one cast, and annealed together confirm

TABLE II.—*Showing the Influence of Varying Casting Temperature on the Properties of small Iron Castings* *

Test Bars, 0·5 *in. diameter* × 16 *in. long.* *Length of piece under test*, 9 *in.*

No	Analysis.						As Cast.	Heated for Three Periods of 7 hours at 1000° C.	Heated to 1000° and slowly cooled.
	CC.	Gr.	Si.	Mn.	S.	P.	Maximum Stress. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Maximum Stress. Tons per sq. in.
A 50	3·4	..	0·04	0·03	0·03	0·02	6·5	5·0	4·9
51	,,	...	,,	,,	,,	,,	8·0	7·3	10·0
52	,,	..	,,	,,	,,	,,	6·2	6·9	7·5
B 53	3·4	0·06	0·11	0·10	0·02	0·02	5·3	8·6	7·3
54	,,	,,	,,	,,	,,	,,	9·1	13·5	13·0
55	,,	,,	,,	,,	,,	,,	8·4	10·0	8·9
C 56	3·3	0·21	0·35	0·18	0·04	0·013	4·0	7·5	8·4
57	,,	,,	,,	,,	,,	,,	8·9	10·6	14·0
58	,,	,,	,,	,,	,,	,,	6·4	8·3	9·0
D 59	3·0	0·35	0·45	0·17	0·04	0·017	5·0	Not tested.†	11·3
60	,,	,,	,,	,,	,,	,,	8·3	10·0	14·1
61	,,	,,	,,	,,	,,	,,	7·1	9·3	11·2
E 62	...	...	0·61	0·08	0·02	0·012	5·6	7·0	8·9
63	...	...	,,	,,	,,	,,	9·0	9·8	13·6
64	...	..	,,	,,	,,	,,	6·7	6·5	11·0
F 65	..	..	0·80	0·09	0·02	0·014	6·5	7·9	9·4
66	...	.	,,	,,	,,	,,	8·0	10·0	14·5
67	...	..	,,	,,	,,	,,	6·1	9·2	10·3
G 68	.	..	1·12	0·08	0·03	0·015	7·6	Not tested.†	8·6
69	...	..	,,	,,	,,	,,	11·0	,,	13·2
70	..	.	,,	,,	,,	,,	6·7	,,	8·3
H 71	...	...	1·47	·30	0·03	0·011	7·0	7·6	7·0
72	...	..	,,	.	,,	,,	10·0	11·1	12·8
73	..	.	,,	,,	,,	,,	8·8	9·0	8·3
I 74	...	..	2·1	0·40	0·05	0·02	5·8	4·0	5·5
75	...	.	,,	,,	,,	,,	12·0	8·0	12·0
76	...	.	,,	,,	,,	,,	5·5	6·2	5·8
J 77	..	...	2·7	0·30	0·04	0·02	5·3	Not tested.†	7·4
78	...	...	,,	,,	,,	,,	10·4	,,	12·1
79	...	.	,,	,,	,,	,,	7·5	,,	9·0

* The small diameter of these castings, and the relatively rapid solidification, prevent them showing the effect of an increasing content of silicon. A similar series of bars 1 inch diameter is contemplated.

† Seven of these bars were too warped to test.

Nos. 80 to 83. With a harder steel poured at selected temperatures from the fair heat downwards, the extensibility falls from 22.5 to 6.5 per cent. The results obtained from Nos. 90 to 93 illustrate not only the survival of casting temperature, but also show a type of steel not amenable to subsequent treatment.

The difficulty of obtaining typical "high" casting temperatures from mild crucible steels has been referred to; practically there is no danger of such metal being poured at too high a temperature.* There is, however, a strong possibility of the steel being cast too cold. A peculiar feature of mild crucible steels poured at "fair" and "cold" heats lies in the fact that generally their tensile properties are very similar if not identical; the actual properties of these steels are, however, anything but similar, and from one crucible two castings may be obtained, one of which may be dangerously brittle.

Table IV embodies some of the tensile results obtained from crucible steels. From the first three steels a steady fall in tenacity with a falling temperature is perceptible. Nos. 97 to 100 embrace two steels of nearly uniform composition in three conditions, viz., cast, annealed, and forged, each condition including two distinct casting temperatures. This series is intended as a comparison of casting temperature on castings and forgings Nos. 99 to 100 represent two ingots poured at the "fair" and "cold" heats respectively; they were cogged down to one inch round bars under identical conditions — in other words, reheated to the same temperature and both finished at the same heat.

The tensile results obtained from these steels as cast and forged are worthy of attention, and it will be noted that here the influence of casting temperature is not shown.† No. 98A in bending reached an angle of 160°, and then broke "short." The two ends of 97A were brought together without sign of flaw, both 99 and 100 being similarly treated. Yet in breaking pieces of 98A by means of a hammer decisive brittleness was shown and approximately these pieces required only one-half the energy necessary to fracture similar pieces of 97A. This type of brittleness appears to be induced by a low casting temperature, and provided the steel has not been overheated,

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* This statement applies only to mild castings, and does not include tool steels.

† When melting, the "fair" heat was not exceeded in either case.

TABLE III —*The Influence of Varying Casting Temperature on the Properties of Steel Castings of Identical Composition, poured from one Heat*

No.	Analysis.					Condition.	Mechanical Properties.				Remarks.
	CC.	Si.	Mn.	S.	P.		Elastic Limit. Tons per sq. in.	Maximum stress. Tons per sq. in.	Elongation per cent. on 2 in.	Reduction of area per cent.	
80	0·29	0·07	0·16	0·07	0·06	As cast	13·5	20·3	5·0	7·7	Poured in rotation at intervals from "high" to "low" during one cast.
81	,,	,,	,,	,,	,,	,,	14·3	24·2	9·0	12·9	
82	,,	,,	,,	,,	,,	,,	13·6	26·0	10·0	10·0	
83	,,	,,	,,	,,	,,	,,	12·8	25·0	8·5	10·8	
80A	,,	,,	,,	,,	,,	Annealed	12·5	24·2	9·5	18·0	80 to 83 annealed.
81A	,,	,,	,,	,,	,,	,,	13·5	27·2	24·0	32·3	
82A	,,	,,	,,	,,	,,	,,	13·3	27·0	12·5	17·5	
83A	,,	,,	,,	,,	,,	,,	13·2	25·5	8·0	12·0	
84A	0·28	0·15	0·29	0·06	0·05	Annealed	16·2	30·9	15·5	16·4	Representing three typical casting temperatures from one cast.
85A	,,	,,	,,	,,	,,	,,	15·4	28·0	33·5	45·6	
86A	,,	,,	,,	,,	,,	,,	16·4	30·3	27·5	39·2	
87A	0·51	0·11	0·42	0·06	0·05	Annealed	18·0	35·4	22·5	27·3	Fair to low casting temperature from one cast.
88A	,,	,,	,,	,,	,,	,,	17·0	36·7	20·0	16·7	
89A	,,	,,	,,	,,	,,	,,	15·7	36·2	6·5	8·4	
90	0·20	0·04	0·38	0·15	0·06	As cast	11·7	14·2	3·5	7·0	Example of the influence of varying casting temperature on a mild steel fairly high in sulphur.
91	,,	,,	,,	,,	,,	,,	14·8	21·5	5·0	8·6	
92	,,	,,	,,	,,	,,	,,	13·8	21·4	6·0	9·1	
93	,,	,,	,,	,,	,,	,,	12·6	17·5	3·5	8·0	
90A	,,	,,	,,	,,	,,	Annealed	11·4	15·8	6·5	11·2	90 to 93 annealed.
91A	,,	,,	,,	,,	,,	,,	13·0	22·1	7·5	13·4	
92A	,,	,,	,,	,,	,,	,,	12·5	21·8	10·0	9·2	
93A	,,	,,	,,	,,	,,	,,	12·2	20·8	10·0	9·0	
90HT	,,	,,	,,	,,	,,	Heated to 1000° C., and slowly cooled.	13·5	15·5	5·0	8·0	90A, 91A, 92A, and 93A heated to 1000° C., and slowly cooled.
91HT	,,	,,	,,	,,	,,		14·2	15·7	8·0	9·0	
92HT	,,	,,	,,	,,	,,		14·9	22·9	11·0	12·0	
93HT	,,	,,	,,	,,	,,		14·1	20·7	10·0	11·0	

is not, as a rule, evidenced in the results obtained from a tensile test.

Professor Arnold has shown the existence of two distinct types of brittleness:* (1) mechanical brittleness, and (2) vibratory brittleness. The first is apparent, whilst the second type is met with in steels of good tensile properties, but which under certain conditions are liable to fracture under alternation of stress at a stress far below their elastic limit. Mr. E. G. Izod† has recently, in a paper read before the British Association, confirmed Professor Arnold's results. Professor Le Chatelier,‡ in speaking of accidental fractures, has stated their source to be in the intermittent brittleness of the metal, "a brittleness not made apparent in the tensile test, but which is felt under certain conditions, especially when the metal is in use."

Early in the present research the question of brittleness assumed importance, and it was specially desired to ascertain if the second type described by Professor Arnold was a function of casting temperature. The results shown on Table V are worthy of note, steel No. 97 withstood sixty-eight reversals of stress, whilst No. 98 fractured on forty-eight reversals. Even after annealing 98A is not brought to the same level as 97 in the

TABLE V — *The Influence of Varying Casting Temperature on the Properties of Steel as Evidenced by Alternation of Stress*

DATA. — 270 reversals per minute, $\frac{9}{16}$-inch stroke, test-piece $\frac{3}{8}$ inch × $\frac{3}{8}$ inch

No.	Casting Temperature	Condition	Reversals to Complete Fracture	Max. Stress Tons per Square Inch	Elongation Per Cent on 2 Inches
97	1550° to 1600°	As cast	68	35.8	12.5
98	1470° to 1500°	"	48	34.2	11.5
97A	1550° to 1600°	Annealed	122	27.0	17.5
98A	1470° to 1500°	"	62	28.2	18.5
99	1550° to 1600°	Forged	546	40.9	27.5
100	1470° to 1500°	"	172	40.1	28.0

* "Minutes of Proceedings of the Institution of Civil Engineers," vol. cliv, supplement.

† "Engineering," vol. lxxvi, No. 1969, page 431.

‡ *The Iron and Steel Metallurgist,* vol. vii, No. 2.

TABLE IV.—*The Influence of Varying Casting Temperature on the Properties of Steel Castings*

No.	Casting Temperature.	Analysis C.C.	Si.	Mn.	S.	P.	Condition.	Mechanical Properties. Elastic Limit. Tons per sq. in.	Maximum Stress. Tons per sq. in.	Elongation per cent. on 2 in.	Reduction of area per cent.	Bending Angle.	Remarks.
94	1500° C.	0·47	0·22	1·04	0·05	0·016	As cast	24·0	38·6	4·5	6·0	30° broken	Three 50-lb. crucibles charged together but drawn at different temperatures.
95	1481° C.	0·50	0·20	0·96	0·05	0·017	,,	24·6	36·4	3·0	5·4	23° ,,	
96	1431° C.	0·47	0·20	1·00	0·05	0·016	,,	18·5	31·0	2·5	3·8	10° ,,	
94A	1500° C.	0·47	0·22	1·04	0·05	0·016	Annealed	18·0	37·1	13·0	15·2	80° broken	Nos. 94, 95, and 96 annealed.
95A	1481° C.	0·50	0·20	0·96	0·05	0·017	,,	18·1	36·4	7·5	9·2	60° ,,	
96A	1431° C.	0·47	0·20	1·00	0·05	0·016	,,	16·8	22·5	3·0	8·1	35° ,,	
97	1550° to 1600° C.	0·36	0·22	0·89	0·02	0·02	As cast	18·4	35·8	12·5	12·5	75° broken	From one crucible. 98 poured 2 min. later than 97.
98	1470° to 1500° C.	,,	,,	,,	,,	,,	,,	18·0	34·2	11·5	17·4	80° ,,	
97A	1550° to 1600° C.	,,	,,	,,	,,	,,	Annealed	14·2	27·0	17·5	17·4	180° unbroken	97 and 98 annealed.
98A	1470° to 1500° C.	,,	,,	,,	,,	,,	,,	16·0	28·2	18·5	18·0	160° broken	
99	1550° to 1600° C.	0·37	0·18	0·87	0·03	0·02	Forged	25·6	40·9	27·5	54·0	180° unbroken	From one crucible. 100 cast 2 min. later than 99.
100	1470° to 1500° C.	,,	,,	,,	,,	,,	,,	24·5	40·1	28·0	50·0	180° ,,	
101	1611° C.	0·29	0·14	0·92	0·06	0·02	As cast	18·5	30·9	7·5	13·1	...	From one crucible. 1½ min. interval.
102	1560° C.	,,	,,	,,	,,	,,	,,	18·5	30·1	7·0	12·1	...	
101A	1611° C.	,,	,,	,,	,,	,,	Annealed	16·0	29·1	19·5	18·4	180° unbroken	101 and 102 annealed.
102A	1560° C.	,,	,,	,,	,,	,,	,,	15·2	28·4	18·5	18·4	105° broken	
103	1653° C.	0·08	0·04	0·06	0·03	0·01	As cast	...		...		180° unbroken	From one crucible. 1 minute interval.
104	1613° C.	,,	,,	,,	,,	,,	,,	10·3	18·7	15·0	27·4	180° ,,	
103A	1653° C.	,,	,,	,,	,,	,,	Annealed	...	...	...		180° unbroken	103 to 104 annealed.
104A	1613° C.	,,	,,	,,	,,	,,	,,	7·2	18·5	35·0	52·2	180° ,,	

cast condition. The forged steels are, however, of greater moment, the fair heat, No. 99 requiring 546 reversals to effect fracture, whilst the cold one, No. 100 required only 172. At present any definite statement on these results is hardly possible; there is, however, a strong probability that the cause of many mysterious fractures of steel of high ductility, as shown by the tensile test, may be traced to the original ingot being cast at either too high or too low a temperature.

The severity of the foregoing test may be exemplified by the following results. A casting showing a tenacity of 28 tons

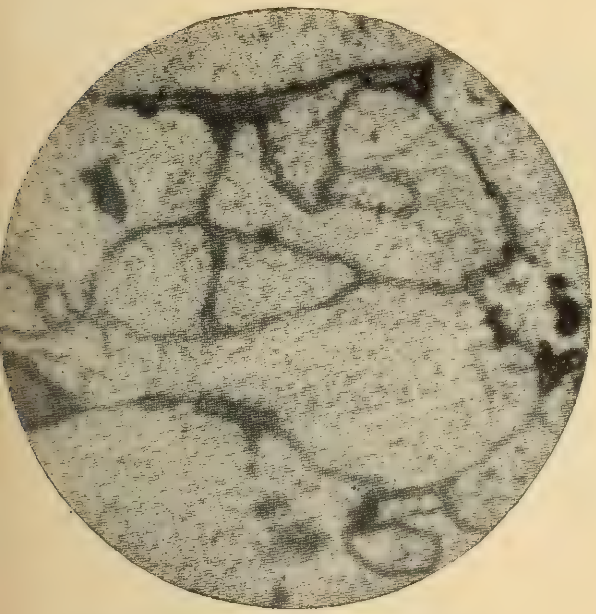

Fig. 1. Nearly Pure Iron, as Cast. Casting Temperature, 1,653° C.

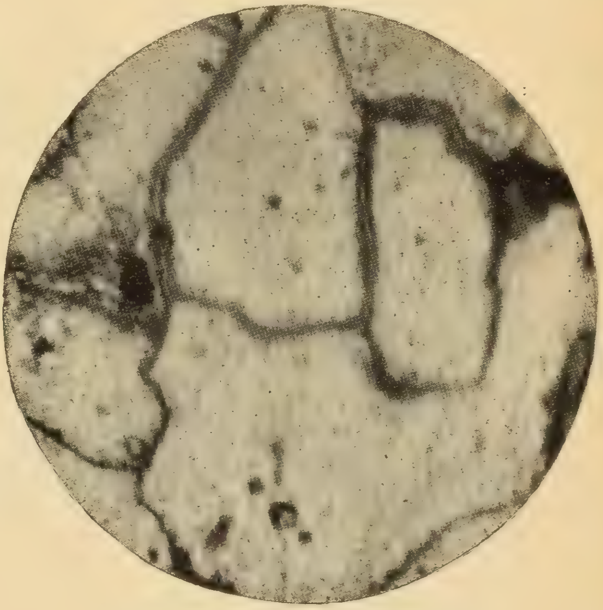

Fig. 2. Nearly Pure Iron, as Cast. Casting Temperature, 1,613° C. Magnified 360 Diameters.

per square inch and an elongation of 26 per cent fractured after forty-one reversals. Pure iron as cast and annealed fractured on 72 and 198 reversals respectively. As an extreme illustration, a casting of 38 tons maximum stress and 4 per cent elongation fractured on four reversals, a similar casting poured at a slightly lower temperature broke on eight reversals. After annealing, these results were raised to 26 and 102 reversals respectively.

The Influence of Casting Temperature on Specific Gravity. — Much work has been devoted to this section, and with iron or steel no correlation has at present been established between

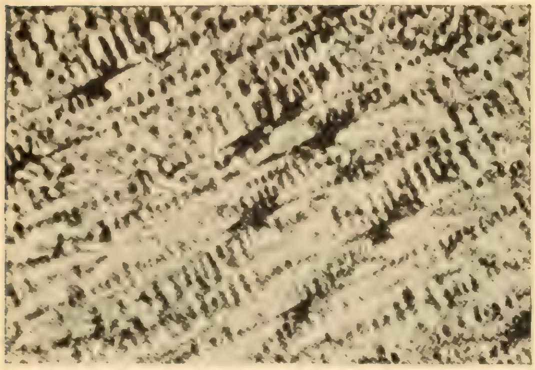

Fig. 3. White Cast Iron. Magnified 58 Diameters.
Casting Temperature, 1,320° C.
Maximum Stress. 10.7 Tons.

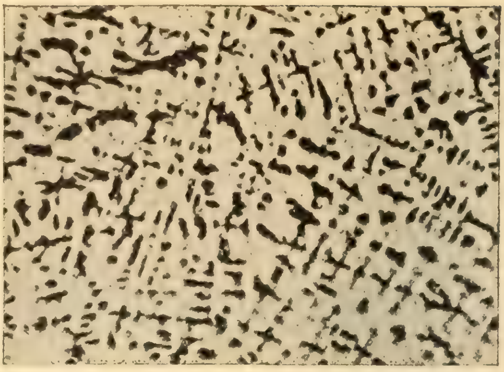

Fig. 4. White Cast Iron. Magnified 58 Diameters.
Casting Temperature, 1,230° C.
Maximum Stress, 15.9 Tons.

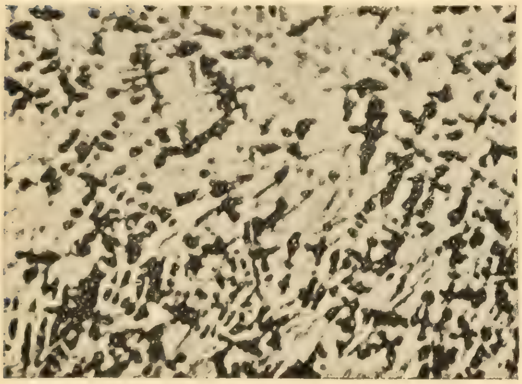

Fig. 5. White Cast Iron. Magnified 58 Diameters.
Casting Temperature, 1,120° C.
Maximum Stress, 12.1 Tons.

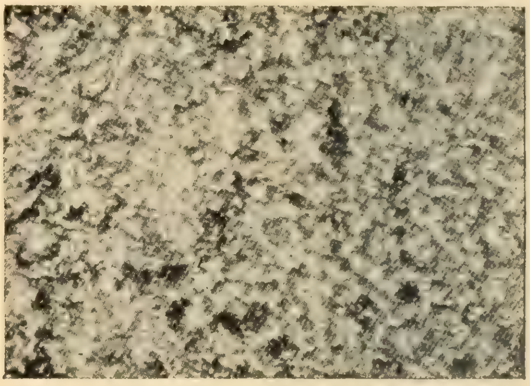

Fig. 6. White Cast Iron. Annealed. Magnified 58 Diameters.
Casting Temperature, 1,320° C.
Maximum Stress, 20.6 Tons.

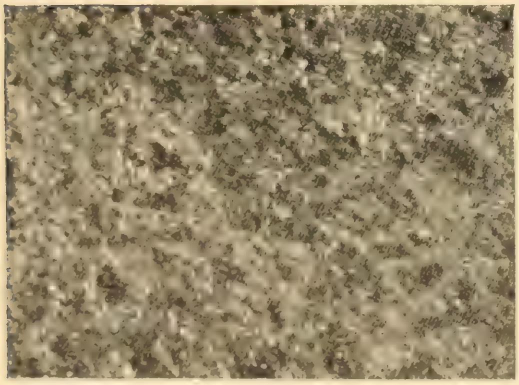

Fig. 7. White Cast Iron. Annealed. Magnified 58 Diameters.
Casting Temperature, 1,230° C.
Maximum Stress, 29.2 Tons.

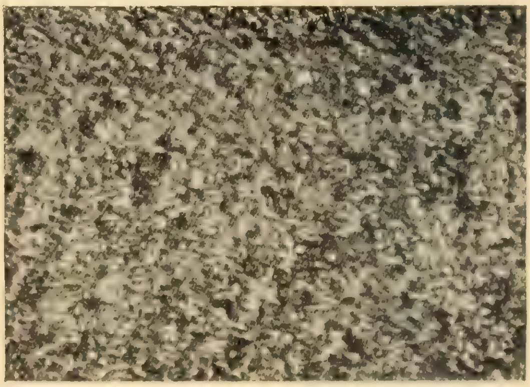

Fig. 8. White Cast Iron. Annealed. Magnified 58 Diameters.
Casting Temperature, 1,120° C.
Maximum Stress, 26.5 Tons.

casting temperature and density. However, as shown in the first part of this research, the appearance of runner heads is often a good index as to whether the casting temperature has been suitable or not. Similarly, the top surface of a steel ingot may also serve as a guide; reference to Fig. 21 shows three mild ingots from one cast, representing three casting temperatures.

Microscopical. — On the whole, the net results of this section are not comparable with the work expended on it. The chief effort was directed to ascertain if the varying mechanical

Fig. 21. — Three Siemens Steel Ingots.
A "Hot." B "Fair." C "Cold."

properties of iron or steel poured from one ladle could be satisfactorily explained by the influence of casting temperature on structure. The "fair" casting heat, as a rule, favors a less distinct type of crystallization than either the "high" or "low" heats. The "low" heats are characterized by a very distinct type of crystallization, and with medium carbon steels the junctions between the pearlite and ferrite are very sharp. The fact has also been proved that the "loose" structure of the "high," the "interlocked" structure of the "fair," and the "sharp" one of the "low" casting heats survive an equal heat treatment.

The bulk of the work, however, indicates that the influence of casting temperature is exerted on the crystal junctions, for with each metal or alloy examined a certain casting temperature

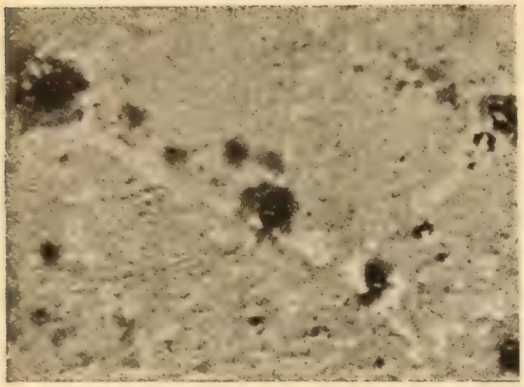

Fig. 9. Gray Cast Iron. Heat Tinted.
Magnified 58 Diameters.
Casting Temperature, 1,400° C.
Maximum Stress, 9.7 Tons.

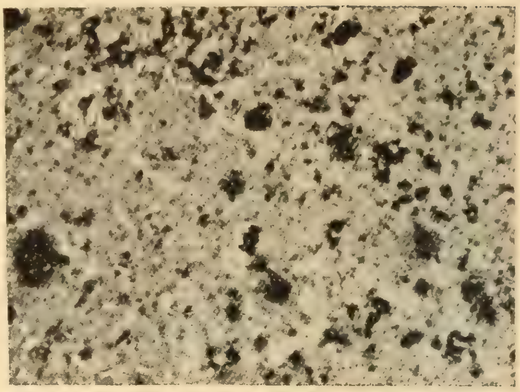

Fig. 10. Gray Cast Iron. Heat Tinted.
Magnified 58 Diameters.
Casting Temperature, 1,245° C.
Maximum Stress, 10.6 Tons.

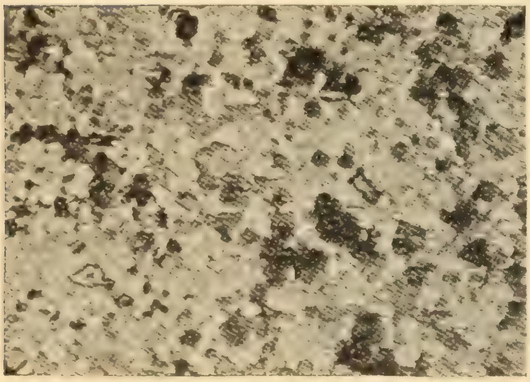

Fig. 11. Steel, No. 84A.
Elongation per cent, 15.5.
Magnified 58 Diameters.

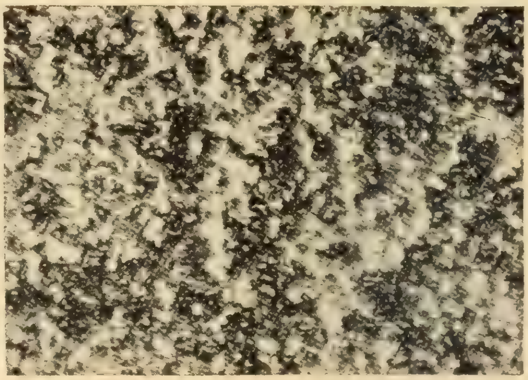

Fig. 12. Steel, No, 85A.
Elongation per cent, 33.5.
Magnified 58 Diameters.

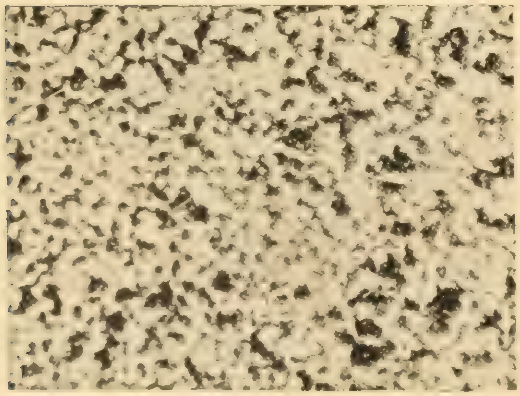

Fig. 13. Steel, No. 86A.
Elongation per cent, 27.5.
Magnified 58 Diameters.

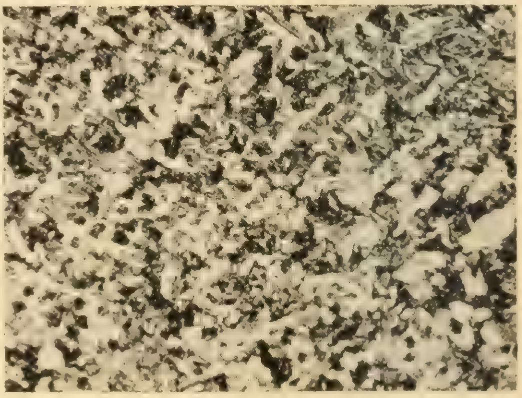

Fig. 14. Steel, No. 87A.
Elongation, per cent, 22.5.
Magnified 58 Diameters.

(the fair one) favors a distinctly stronger type of internal cohesion.

Thus when sections of pure metal, cast at typical "fair" and "low" heats, are etched under strictly comparative conditions, the crystal junctions of the latter appear before the former, and on termination of the etching the junctions of the "cold" metal are more pronounced, i.e., deeper and broader. These conclusions are based on results obtained from zinc, tin, copper, and iron. References to Figs. 1 and 2 illustrate this feature, and the difference in the crystal junctions of nearly pure iron, cast at 1,653° C. and 1,613° C., is readily apparent. In this and the following cases all etching conditions are strictly comparative; that is, each set of sections etched simultaneously in one dish and for exactly the same time.

In connection with Figs. 1 and 2, Professor Arnold described similar features in 1901,* and the following quotation from his research is included owing to its direct bearing: "On deeply etching the two under exactly the same conditions, FeB presented very large ferrite crystals with close joints, whilst 473 showed small crystals with loose junctions — that is to say, the etching acid developed broader spaces between them."

The influence of casting temperature on the structure is well shown in the case of white cast iron in Figs. 3 to 5. The noteworthy feature is that these structures, after a complete rearrangement due to the decomposition of the cementite, still show a difference, as illustrated in Figs. 6, 7, and 8, The high mechanical properties of Fig. 7 are readily explained by its structure, or rather its lack of structure, for the constituents so merge one into the other as to give the characteristic interlocking or interwoven type, whilst Figs. 6 and 8 are distinctly sharp.

Under various forms of etching the gray cast irons presented comparatively little difference, and practically none that could be definitely stated as due to casting temperature. On heat-tinting, the high temperature casting showed a large and irregular cellular structure, the "fair" casting heat presented similar features though on a much smaller scale, none of the cells being continuous, whilst the "cold" casting had a distinctly sharp appearance. Figs. 9 and 10 reproduce the "high" and

* "Journal of the Iron and Steel Institute," 1901, No. I, page 175.

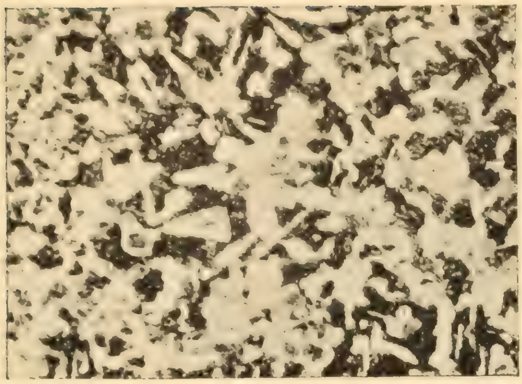

Fig. 15. Steel, No. 88A.
Elongation per cent, 20.0.
Magnified 58 Diameters.

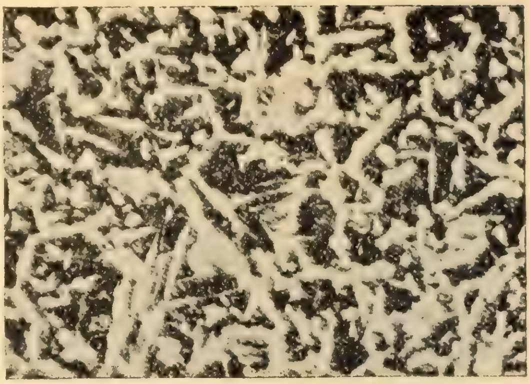

Fig. 16. Steel, No. 89A.
Elongation per cent, 6.5.
Magnified 58 Diameters.

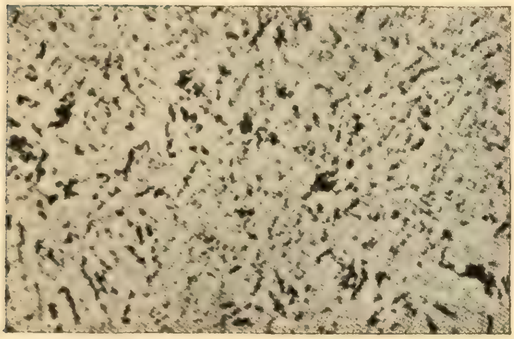

Fig. 17. Steel, No. 90.
Maximum Stress, 14.2 Tons.
Steel in the Cast Condition.
Magnified 58 Diameters.

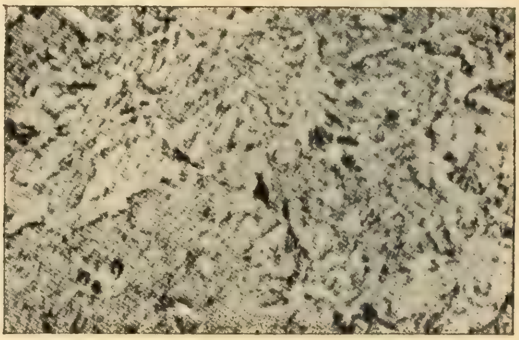

Fig. 18. Steel, No. 91.
Maximum Stress, 21.5 Tons.
Steel in the Cast Condition.
Magnified 58 Diameters.

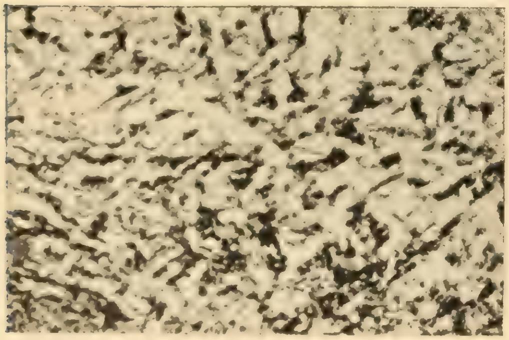

Fig. 19. Steel, No. 92.
Maximum Stress, 21.4 Tons.
Steel in the Cast Condition.
Magnified 58 Diameters.

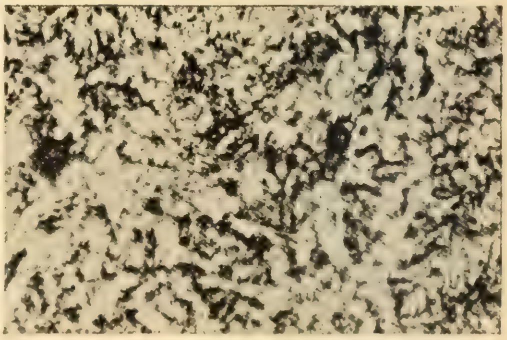

Fig. 20. Steel, No. 93.
Maximum Stress, 17.5 Tons.
Steel in the Cast Condition.
Magnified 58 Diameters.

"low" gray irons, and there the curious cellular structure referred to will be noted.

In Figs. 11, 12 and 13 the structures of steels 84A to 86A are reproduced. The first of these steels was cast at a temperature probably the highest possible for mild steel. The structure of the annealed steel (Fig. 11) is characterized by the distinctly sharp ferrite junctions, no similar junctions showing in Figs. 12 and 13. The merging of pearlite and ferrite one into the other with no apparent junction, typical of the "fair" casting heat, is well shown in Fig. 12; whilst in Fig. 13 these constituents are showing signs of a sharper separation.

Figs. 14, 15 and 16 reproduce the structures of three annealed castings of higher carbon content, commencing with the fair casting heat. The interlocked and broken structure of Fig. 14 gives place, with a falling casting temperature to the sharper structures of Figs. 15 and 16. These steels, poured from one cast at different temperatures, and simultaneously annealed under absolutely identical conditions, form very telling examples of the survival of the influence of casting temperature through prolonged heat treatment.

Finally, Figs. 17, 18, 19 and 20 represent four structures illustrating steels 90 to 93 in the cast condition. These steels were poured at intervals from "high" to "low." Fig. 17 is apparently the best structure of the four, and yet it represents a tenacity of only 14.2 tons per square inch.

Practical Consideration. — This portion has been already treated in the first part of this research.* It may be well, however, to state again that a suitable casting temperature for any given alloy is not constant, but varies with the form and weight of the casting. Other determining conditions are the rate of pouring, the form of runner and gate, and the distance traveled by the metal before entering the mold. By taking advantage of these determining conditions, and commencing with a sufficiently high casting temperature, matters can be readily arranged so that each mold is poured at the correct heat. In determining this correct heat, experience must, until a very considerable advance has been made in pyrometer methods, be the only guide. Empirical though this may be, when carefully applied regularly successful results follow.

* "Journal of the Iron and Steel Institute," 1903, No. I, page 457.

ELECTROLYTIC IRON *

By C. F. BURGESS and CARL HAMBUECHEN

A great deal of attention has been devoted of late to the application of electrical energy to the metallurgy of iron and some of the results attained seem to point to developments of industrial importance. Most of the attempts to apply electrical energy have been through its transformation into heat for use in various smelting and reduction processes. That the electrolytic as well as the electrothermal effect might be utilized industrially does not seem to have been considered seriously, as it has been commonly held that the difficulties inherent in the deposition of iron are such as to preclude its playing an important part in the industrial electrometallurgy of this element.

It has, however, been shown as a result of recent experimental work carried on in the laboratory of Applied Electrochemistry of the University of Wisconsin, that electrolytic iron can be produced in such quantities and at such cost as to make it a material of commercial as well as of scientific importance should sufficient demand for it arise.

A survey of available literature on the subject of electrolytic iron leads naturally to the assumption that its deposition is difficult to accomplish and that there are few solutions from which it can be deposited. Moreover, it has been held that a satisfactory quality of deposit can be attained only by the use of very low current densities and an exceedingly slow rate of deposition. Practically the only uses to which electrolytic iron has been put are in the so-called "steel facing" of dies and electrotypes and as a material for investigating the properties of the pure metal.

The hardness of electrolytic iron which makes it especially suited to the facing of electrotypes is due to the occluded hydrogen which is practically the only impurity present. In fact the very term "electrolytic iron" is commonly assumed to be synonymous with "pure iron." In just what manner the hydrogen is held by the metal is a matter of doubt, it being claimed by some that it is simply condensed and by others that it forms a definite

* Paper read at the April (1904) Meeting of the American Electro-Chemical Society.

hydride. Such iron may contain this gas in quantities equal to several hundred times the volume of the metal, and it can be almost entirely freed from it by heating. Certain investigators have found that electrolytic iron contains carbon in appreciable quantities, while others have found that carbon is absent.

Dr. John A. Mathews (" Alloy Steels," " Mineral Industry " for 1902) states that " Pure iron may properly be classed among the ' rare metals '; thousands of tons of iron alloyed with impurities from a fraction of one per cent upward are produced annually but not a pound of iron in its pure elemental condition has ever been made under ordinary smelting conditions. By ' pure ' we mean in a condition comparable with that in which the precious metals are produced or as pure as the best electrolytic copper and nickel. . . . Just as pure iron is a chemical curiosity, so also is an alloy containing only iron and carbon. In practice at least four other solid elements occur fortuitously in all steels, viz., manganese, silicon, sulphur and phosphorus."

Something over two years ago the authors of this paper undertook an experimental investigation of the conditions suitable for electrolytically depositing iron, and this work has proceeded almost without interruption since that time. The primary object of the investigation was to produce, if possible, pure iron in such quantities and at such cost as to make it an available material for further inquiry into its properties. Since our attention has been confined almost exclusively to this phase of the problem, the observations which have been made as to the physical and chemical properties of the product are by no means exhausted, and indeed are considered only as preliminary to a more extensive research which it is hoped to take up in the future.

The preliminary work consisted in testing the various electrolyte materials which had been suggested previously, and from these the most promising were selected as the basis for further trials. It is needless to record here the many hundreds of tests which were made, for most of them were unsuccessful, nor is it necessary to recite the difficulties encountered. The investigation was necessarily a slow one, since many of the trials required days and even weeks of operation before conclusions could be drawn as to their success. A large number of iron salts were used, and the effects of variations of density of solution, current densities, temperature, agitation of electrolyte and various other

factors were noted. As a result of such observation, ferrous sulphate with a certain percentage of ammonium sulphate was chosen as affording the most satisfactory results, and the process as it is now being operated on a small experimental scale may be briefly described as follows: The electrolyte consists of ferrous and ammonium sulphates; the current density at the cathode is six to ten amperes per square foot of cathode surface and at the anode slightly less; the electromotive force for each cell is slightly under one volt; the temperature of electrolyte is about 30° C.; the anodes consist of ordinary grades of wrought iron and steel; the starting-sheets for the cathodes are of thin sheet iron previously cleaned of rust and steel.

One of the most serious difficulties encountered was in obtaining a thick deposit of iron. While it was proved that there is a considerable range of conditions under which iron can be deposited uniformly and densely for a few hours, or perhaps for a few days, it was almost always found that the surface would become so rough or pitted, or that such a rapid treeing would take place, or that the deposit would curl up to such a degree that it was necessary to discontinue the experiment and start a new one under different conditions. But improvements have been gradually effected, until at the present time it is possible to continue the run four weeks without replacing the cathodes. At the end of such time the cathode reaches an average thickness of about three-quarters of an inch and the surface is so rough and nodular that it is not considered advisable to carry the deposition further.

The current efficiency of deposition is very closely 100 per cent, that is, there is a deposition of about one gram per ampere hour. The electromotive force being one volt gives about 2.2 pounds of iron per kilowatt-hour. Since all the factors which go to make up the cost of large scale production cannot be accurately determined from a small scale experiment it is impossible to state from our investigations what would be the cost of working on an industrial scale. For the past six months three tanks have been maintained in almost continuous operation, these tanks having the dimensions 8 inches wide, 13 inches long, 15 inches deep, and containing two anodes and one cathode. The finished cathodes from these tanks weigh about 20 lbs., and constitute, perhaps, the largest pieces of electrolytic iron which have, up

to the present time, been produced. The total amount of the material which has been produced from all of our experiments is about one-half ton.

A run of two months' duration was made to determine the extent of the deterioration of the electrolyte, resulting in the conclusion that the solution can be kept in good working condition with little trouble or expense. It would appear, therefore, that the cost of refining, aside from fixed charges on plant, and with power at $30.00 per kilowatt-year, would be under one-half cent per pound of iron, thus placing it not greatly in excess of the cost of refining copper.

Even with these figures realized, whether or not electrolytic iron can be profitably produced depends upon the uses which can be made of the refined metal. These in turn depend upon its properties, the most striking of which is its purity. Alhough our work was directed toward the production of electrolytic iron in a dense and massive condition rather than in a high degree of purity, analyses which have been made show the purity to be in excess of 99.9 per cent. Not a trace of carbon was detected, and silicon, manganese and other impurities commonly found in iron appear to be absent. The only impurity which has been detected is hydrogen, which is present in appreciable quantities in the metal as taken from the electrolytic tanks. This gaseous element in its physical or chemical combination with iron influences, in a most striking manner, the physical properties of the metal. The hydrogen can be driven off almost completely if not entirely by heating to a white heat, the evolution commencing at a temperature below 100° C. and becoming rapid at a temperature below a red heat. Electrolytic iron heated in a Thomson welder or even in a Bunsen burner has been observed to give off hydrogen so rapidly that it ignites and continues to burn after removing the source of heat, presenting an appearance similar to that which would be produced by dipping the iron in alcohol and igniting it. The metal containing the hydrogen is so hard that it can be filed or sawed only with difficulty and is so brittle that it is readily shattered by a sharp blow from a hammer. After the expulsion of the gas it becomes softer and after having been raised to a welding temperature it assumes properties of malleability and toughness similar to those of Swedish iron.

The iron when heated in a forge fire can be readily welded

and forged into any desired shape, and various test samples were made in this way. During such working, however, impurities are introduced, analyses invariably showing the presence of a very small percentage of carbon. The cathodes, three-fourths of an inch in thickness, have a surface so rough that they cannot be rolled satisfactorily into sheets, though it is possible that improvements can yet be made in this respect which will enable smooth surfaces to be obtained. The deposit adheres so loosely to the starting sheets that it can be removed readily.

A considerable amount of work has been expended in the attempt to melt electrolytic iron without at the same time introducing impurities. The difficulties that lie in the way of doing this, however, are great on account of the high temperatures necessary, and the affinity which the iron at such temperature has for many of the elements. The melting temperature of the pure iron seems to lie closely to that of platinum, though actual values have not as yet been determined from lack of suitable measuring instruments. Various forms of electric furnaces have been constructed for this purpose, a furnace of the inductor type appearing to be the most suitable for preventing the introduction of carbon. Results which have been somewhat satisfactory have been obtained by heating a molten electrolyte between graphite electrodes to a suitable temperature and introducing the metal into such molten bath. The metal thus produced is tough and malleable, while it also has a fracture of coarse crystalline nature. The affinity which the iron has for carbon is shown by the fact that it can be readily melted in a graphite crucible, while a silica crucible heated to a considerably higher degree melts before the iron in it begins to flow. The absorption of the carbon in the former case produces a fusible alloy of iron.

Experiments have shown that the hysteresis, permeability, and electrolytic resistance of electrolytic iron are greatly influenced by the amount of hydrogen in it. An iron ring was deposited in such form that a hysteresis and permeability loop could be determined by the Ewing method. It was found that by heating in boiling water the hysteresis was lowered several hundred per cent. By futher heating in an oil bath to 200 degrees the value was decreased still further, but to a smaller extent than in the first heating, and upon attempting to heat it to 500 degrees the ring broke and the experiment was therefore interrupted.

Certain samples of forged iron have shown permeability values equalling or even exceeding those of the highest permeability standard samples of Swedish iron. Other samples prepared under apparently identical conditions showed much poorer results, so that it is impossible as yet to draw definite conclusions as to the magnetic properties of electrolytic iron.

It having been shown that it is possible for electrolytic iron to be produced at a small cost, the question naturally rises as to what uses there may be for it. The first suggestion which naturally presents itself is that on account of its purity it would serve as a basis for investigating the properties of iron and its alloys. Investigations having for their object the determination of the influence of various elements alloyed with iron as regards its electrical properties have been unsatisfactory on account of the presence of other impurities which modify or mask the effect of the element which it is desired to study. Starting with the pure iron, therefore, alloys of a predetermined and definite composition can be produced, thus making such investigations of greater simplicity. Unless the difficulties encountered in the working of electrolytic iron on account of its roughness offer too serious an objection, it should compete favorably with the purer grades of commercial iron which are used for various purposes and which sell for three cents and upwards per pound.

Electrolytic iron naturally offers the means of manufacturing chemically pure iron compounds and for standardizing solutions in the analytical chemical laboratory. The electrolytic iron, in addition to its purity, has an advantage for the purpose just mentioned of rapidly dissolving in an acid solution. A test, which was made to determine the rate at which electrolytic iron and iron wire sold as chemically pure for standardizing purposes dissolves, showed a ratio of one to twelve in favor of the former. By reason of the brittleness imparted by the occluded hydrogen, it can be readily broken up into grains of a desired size and even reduced to a fine powder.

Although the investigations referred to in this paper have covered a considerable length of time, the work which has been done should perhaps be considered only as preliminary to a more extended investigation which it is hoped may be taken up in the future. Summing up the work thus far done shows that it is possible to obtain electrolytic iron in large quantities and at a

reasonable cost, and that, therefore, iron should be added to the list of metals to which the process of electrolytic refining can be applied satisfactorily. It has been demonstrated also that such iron possesses a high degree of purity, though just how closely it approaches absolute purity can be shown only by spectroscopic analyses or by other methods which are more accurate than those which have been available.

STEEL AXLES *

By J. L. REPLOGLE

Can too much importance be attached to this, the most important part of the rolling stock of the railroad systems of to-day?

Which other portion of the car or locomotive has more important functions to perform than the axle?

Upon which other portion does the protection of life and property depend to so great an extent as it does upon the axle?

Upon the care with which its proportions are calculated, its shape designed and its manufacture carried out depends, to a great extent, the successful working of the rolling stock and the transportation of the products of our country.

The railroads of a country are indicative of its strength, resources and importance.

Has any one thing been more responsible for our commercial supremacy than the excellence of our railroad systems and the men to whom the high degree of efficiency found therein is due?

In which other country do we see solid trains of cars, the lading of each of which approximates, and may exceed, the marked capacity of 50 tons?

Would this condition have been possible without the substitution in the working parts of metal with greater strength, tenacity and resiliency than unreliable iron of low elasticity and tensile strength?

The comparative merits of steel and iron for car axles is a

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* Read before Western Railway Club, Chicago, May 17, 1904. Revised by the author for publication in *The Iron and Steel Magazine*.

question which has engrossed the attention of railroad officials and axle makers for many years. We feel justified in saying that the experience of these years has demonstrated that steel is superior to iron for this purpose, not only on account of its greater power of resistance against the shocks and vibrations to which it is subjected in service, but also on account of its greater wearing properties, the friction being less than in the iron axle, where lack of sufficient heat, presence of scale, or other conditions often prevent perfect adhesion of the various constituent parts. Even a perfectly welded iron axle will not allow the high polish and minimum amount of friction obtainable in the steel axle of the proper composition.

Our secretary, Mr. Taylor, has suggested that we divide our paper into subheads, as follows:

A. — Method of manufacture.

B. — Our opinion as to best specification, chemically and physically, and a review of the present Master Car Builders' specifications.

C. — What we have found as a result of the examination of broken axles.

A. — In the early days of steel axles, the steel maker had difficulty in proving the superiority of his product, as there were numerous breakages in service for which he could not account, his chemical analysis indicating that the elements were of the proper proportion to the evident requirements of the purpose. In looking for the cause, he found that while his light hammers of probably 2,000 pounds falling weight were sufficiently powerful for building up iron bars probably one to two inches thick into an axle of approximately 5½ inches diameter, it was entirely inadequate for forging steel axles, as steel, not possessing the welding properties of iron, could not be forged in the same manner.

Instead of building up from bars one to two inches thick, he was compelled to reverse the method and hammer down from a billet about twice the size his finished forging should be.

His hammer not being sufficiently powerful to penetrate throughout the mass did not give the axle that homogeneous structure so essential in a forging subjected to the heavy alternating stresses which a car axle undergoes in service. The internal condition of his axle revealed to him by the end of his

rough forging, which was a deep concave, showing that the surface metal only had expanded and that the inner portion had not received the proper working and consequent homogeneity of structure which he desired. It also showed inclination to "pipe."

He appreciated his position and promptly strengthened it by the installation of heavier hammers of about three times the weight formerly used. While he immediately saw a distinct improvement in his forging (the end now being convex, indicating that the inner portion had received proper attention), the steel axle did not give the absolute satisfaction of which he thought it capable, and an investigation proved to him that heat treatment in the forge was largely responsible.

He reasoned that, as no two parts of the axle were forged at the same temperature, internal strains had set in, which were very detrimental to the forging, and which would have to be relieved. This was particularly evident in locomotive driving axles, which after cutting key-way, thereby relieving strains in the fibers, would often become distorted.

To relieve the injurious strains above stated, he resorted to annealing. By heating the forging to a temperature slightly above the recalescent point, (which, in steel of carbon usually found in axles, would be approximately 1,200° F.) he eliminated all crystallization resultant from the cooling from the forging temperature of about 1,800° F., and a fine amorphous structure was obtained.

Crystallization would of course set in again when the forging was being cooled, but as in the annealing he did not approach within 400° or 500° the temperature at which his axle was forged, the resultant crystallization was comparatively small. While the ductility of the annealed forging was greatly increased, it suffered a slight loss in elasticity.

Realizing the importance of having a high degree of elasticity in his material, which was continually subjected to severe alternating tension and compression, and often torsional strains, the axle maker started to experiment with a view of not only maintaining the elasticity found in the original forging before annealing, but also to increase same.

Various methods have been used to gain this result, among the more prominent being the "Coffin Toughening Process" and

"oil tempering and annealing," either of which give the following results:

1. The elastic limit is increased to a marked degree.

2. The percentage of elongation and reduction of area are greatly increased.

3. A remarkable degree of toughness is obtained.

4. Steel changes from a crystalline to an amorphous state.

5. Internal stresses are eliminated.

6. Uniformity of structure and strength are obtained.

The increase in elasticity is of the greatest possible benefit as it is a recognized fact that once the elastic limit of metal has been passed and the forging therefore distorted, it cannot be depended upon to sustain even minor loads.

In wrought iron forgings the elastic limit probably does not exceed 20,000 pounds per square inch. Steel of, say 0.45 per cent carbon properly treated will show almost three times as much elasticity and is, therefore, much better fitted for the service described.

Realizing that in material of this kind, wherein so much depends, that "the best is none too good," the modern steel manufacturer has installed complete chemical, physical and microscopical laboratories which tell him the results obtained throughout the various stages of the manufacture, and in the final treatment at the annealing furnace he raises or lowers the physical properties to the required specifications, carefully and intelligently guided by reliable pyrometers which show the operator the exact temperature of his furnace at any and all times.

"The method of manufacture," then, we consider of great importance. Our claim that a steel axle properly forged and afterward properly annealed is infinitely superior in strength or wearing properties to the best iron axle, we think can hardly be disputed.

While the art of steel making has been perfected more and more year after year, the material and skill for making the best quality of iron have, on the contrary, retrograded, and at the present time a good grade of iron is scarce, largely on account of the difficulty in obtaining the necessary good quality of scrap, that now available being composed of inferior iron intermixed with pieces of steel of various grades, which produce imperfect welds and irregularities in the finished axle.

This lack of homogeneity permits the torsional strains and friction to separate the fibers of the metal; — longitudinal seams and rough spots develop which finally result in failure of the axle.

B. Specifications. — Our opinion as to the best specification would be an endorsement of the present Master Car Builders' specification with a few exceptions, viz.:

1. We should recommend an increase in carbon, making the limit 0.40 to 0.55 per cent instead of 0.33 to 0.50 per cent, as at present. This would insure greater wear, permitting a higher polish with a consequent reduction of friction, and if properly treated, greater strength, but would necessitate a slight modification of the present drop test.

2. We should insist upon all axles being thoroughly annealed, as by this method only, is the true strength of the steel represented.

3. We would adopt a "maximum weight" clause compelling manufacturers to rough turn forgings on journals and wheel seats to within one-eighth inch of your finished dimensions, thereby eliminating the necessity of your paying for 50 to 75 pounds of excess material per axle, which also necessitates a vast amount of extra work and expense at the railroad shops; subjecting your lathes to both roughing and finishing duties, which is detrimental to the best results in fitting.

4. We should recommend a maximum limit on phosphorus of 0.05 per cent instead of 0.07 per cent, as at present, to compensate for the recommended raise of the carbon by five points, both elements being hardeners, but carbon affecting the ductility less than the phosphorus, and being conducive to greater wearing qualities.

5. We would modify that portion of clause 1 in the specification relating to the rough turning of axles, to read: "Axles must be rough turned on journals and wheel seats to within one-eighth inch of finished dimensions and must be smooth forged between wheel fits."

Rough turning an axle between wheel fits robs the axle of the tough surface skin, which is a very valuable asset.

In this connection, I would cite results of a test made at our works to demonstrate our claims: During a controversy with an inspector of a prominent road which specifies rough turning

all over, we suggested to him that he take two axles of the same heat, one being rough turned to 5⅞ inches in center, the other being smooth forged to the same dimension. These axles were subjected to same treatment throughout and were then tested to breakage. The rough turned axle stood 21 blows of a 1640 pound drop from 43 feet height, and the smooth forged one stood 78 blows, or almost four times as severe a test.

Tensile tests cut from the broken axles showed the same chemical and physical structure.

Extensive tests made at another works by one of the leading railroads specifying this, show that in axles of the average carbon, the smooth forged axle will stand approximately 43 per cent harder test than the rough turned one. Rough turning an axle also makes it more susceptible to rust.

These are but a few tests of the many made along this line, the aggregate of which leads us to believe that the railroads of this country are annually expending hundreds of thousands of dollars on this feature, and are thereby getting an inferior axle.

C. "Broken Axles."—"What we have found as a result of the examination of broken axles" :

In fifteen years' experience in the manufacture of steel axles, the writer recollects of but seven of our axles having failed in service, four of these being due to inferior design, the wheel fit sizes being three-eighths inch under the Master Car Builders' standard dimensions.

We believe this record is due, not so much to the superiority of the steel itself (although the company which I have the honor to represent is the pioneer steel company of America), but to the fact that it is the policy of our company to thoroughly anneal every forging produced, thereby eliminating all forging strains and results of imperfect heat treatment, and restoring to the steel its initial or intrinsic strength.

Our experience with broken axles, therefore, is limited and perhaps other members of the club can give more information on this subject than the writer.

We have, however, seen broken axles around in various railroad shops, the examination of which leads us to the conclusion that failures were due to the fact that steel used was too low in elasticity and tensile strength, steel of probably 0.30 or 0.35 per cent carbon being used.

The failures were due largely to what has been termed "fatigue of metal" and show a detail fracture, a gradual parting of the steel, extending toward the center all around the piece, unquestionably caused by the imposed strains repeatedly approaching the low elastic strength of the soft steel.

The substitution of a steel of higher carbon and elasticity would prevent failure of this kind.

The observations of Dr. Chas. B. Dudley, the eminent chemist of the Pennsylvania Railroad Company, are interesting and pertinent to this subject, and we quote him: "It is obvious that the journal of a car axle gets alternating bending stresses, that is, the metal is subject to alternate tension and compression with each revolution, and that during the life of an axle, these stresses are many thousand, and perhaps million times repeated."

Again, the metal between the wheels is in like manner subjected at each revolution to the same alternating stresses.

The effect of these repeated alternate bending stresses are almost too well known to need comment. Sooner or later, if the stress is high enough, all metal will rupture under these alternate strains.

A marked characteristic of the fractured surface of a piece of metal which has broken from this cause, is that it never presents fibrous appearance in the fracture, but is more or less smooth, possibly due to the fractured parts rubbing against each other, and having the appearance of an old break. It commences where the maximum stress occurs on the surface of the section and gradually works in from the surface until so small a part of the original area is left unbroken that a sudden shock or stress finishes the rupture.

This breaking slowly, a little at a time, led to the description of this fracture as "detail fracture," which will never be confounded with a rupture produced in any other way.

The experience of the Pennsylvania Railroad Company on car axles on this point, may be interesting: Steel axles were first used on the Pennsylvania Railroad in 1875. The maximum calculated fiber stress between wheels was about 15,000 pounds per square inch, and the maximum fiber stress in the journal was about 6,700 pounds per square inch. The steel of these axles was an acid, open-hearth steel, containing from 0.22 to 0.28 per cent carbon, and not over 0.04 per cent phosphorus, and with a tensile

strength of about 65,000 pounds per square inch, and an elongation in two inches of over 25 per cent. So tough was this steel that one passenger car axle was tested under the drop test with 67 blows without rupture. Some 300 of these axles were put in service, and in the course of two years, the journals began to fail from detail fracture. The matter became serious, and a consultation was held as to how to meet the difficulty. There seemed but two ways of procedure; — either to increase the size or to change the nature of the metal. Since an increase in size meant a re-design of all the parts, the latter alternative was chosen, and a metal of 80,000 pounds tensile strength was substituted for the softer steel, no other changes being made. This completely cured the difficulty, and no case of breaking in detail in car axles is known to have occurred since that time, unless the metal was of lower tensile strength than the figure given, or the axle was worn to limit, so that the maximum fiber stress was too high."

Endurance tests made at the Watertown Arsenal by the United States Government on wrought iron and 0.45 per cent carbon steel bars one inch diameter, 36 inches long, loaded in the middle so that the fiber stress was 40,000 pounds per square inch, show a great superiority in favor of the latter.

These bars were rotated 1,500 times per minute, the number of revolutions being recorded.

The average number of revolutions of the wrought iron was 59,000, while the 0.45 per cent carbon steel bars broke after 976,000 revolutions, or 16½ times as severe a test.

To test the value of iron or steel for car axles, and the effect of strains similar to those imposed in service, Mr. Wohler, chief engineer of the Prussian State Railway, constructed machines for the purpose, by which the bars were exposed to vibrating actions and repeated strains within adjustable limits.

1. For straining a cylindrical bar in a manner similar to that in which an axle is acted upon by the load it carries: A bar, placed in bearings, was caused to revolve; to one end (corresponding to journal of axle) was attached a spring, giving a constant downward pull, by which action the bars were bent down at the end to a fixed distance, and, in its rotation, the action of the spring caused it to bend in all directions successively, all around the circumference of the bar, by which means the alternate strains of compression and tension were produced. The

breaking strains of fibrous iron, under these conditions, was from 20,160 to 22,400 pounds per square inch; soft steel, 26,880 to 33,600 pounds per square inch.

Testing further, the effect of repeated strains applied to the center of a revolving axle, in which the fibers in each section are strained in the same direction each time, the tension on each fiber varying between zero and the strain imposed: Fibrous iron broke at a tensile strain of 33,600 to 40,320 pounds per square inch; soft steel at 50,400 to 56,000 pounds per square inch.

Walter E. Koch, formerly of the works of Landore (the original Seimens works) and later of Pittsburg, in his paper on "Fifteen Years' Experience with Open-Hearth Steel," says: "Statistics show in Great Britain that eight iron axles break to every one of steel, and it is astonishing to me that so many iron axles are still in use in this progressive country." Mr. Koch, when written to concerning this statement, said: "I referred to straight and not to crank axles, and at that time there were about half iron and steel in use."

We could cite results of many such experiments made by many men under many circumstances, but it was long ago demonstrated that too much statistical information is not wanted, the average man's aversion to such data being well expressed by Hon. C. D. Wright when he said, "Figures won't lie but liars will figure."

We feel that the steel axle is now so well established that the many experienced gentlemen who are with us to-day can contribute information of far greater value.

THE ELECTRIC AND MAGNETIC PROPERTIES OF ALLOYS OF IRON*

By W. F. BARRETT, F. R. S.

FOR several years past the authors have been engaged in the investigation of the physical properties of an extensive and unique series of alloys of iron, prepared with great care by Mr. R. A. Hadfield, M. Inst. C. E., at the Hecla Steel Works, Sheffield.

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* "Technics," February, 1904.

In preparing the specimens for examination, a great variety of alloys of iron were cast into ingots. Of these latter, 110 were successfully forged into bars, and then, after being heated to a bright red (about 900° C.), were rolled into cylindrical rods of about 0.5 cm. diameter. After being straightened, these rods were forwarded to the Royal College of Science, Dublin, where their electrical and magnetic properties were tested. The rods were then sent back to Sheffield, where they were carefully annealed in an E. and W. position, at a temperature of 1,000° C., the cooling occupying 100 hours, or about four days and nights; they were then returned to Dublin, where their electric and magnetic properties were again carefully determined by the authors. The chemical analyses of the alloys were conducted in the laboratory attached to the Hecla works.

The resistivities of the specimens were determined by observing the drop of potential due to a constant current flowing through each rod, and comparing this with the drop of potential produced by the same current flowing along a standard rod of iron or copper. The length of each rod having been measured, its volume was found by water displacement. A long glass tube, closed at one end, was used for this purpose, the tube being one cm. in diameter, and graduated in lengths of a C. C. The mean sectional area of each rod was calculated by dividing its volume by its length.

The curves in Fig. 1 exhibit at a glance the resistivities (or specific electric resistances) of various alloys of iron. Each curve corresponds to an alloy of iron and one other element, the name of the latter being attached to the curve. The percentage of the added element is plotted horizontally, while the resistivity of the alloy, in microhms per centimeter cube at 18° C., is plotted vertically. The three horizontal broken lines near the bottom of the figure indicate the resistivities of iron when the impurities contained amount to one per cent, 0.5 per cent, and 0.1 per cent respectively.

An inspection of Fig. 1 shows that, of all the alloys examined those containing tungsten differ least from pure iron. The change produced by the addition of even the smallest quantity of carbon is strikingly shown. In fact, other things being equal, a determination of the resistivity affords a rapid and simple method of estimating the amount of carbon present in a sample

of steel, by an inspection of Fig. 1. It should further be noticed that the increase in the resistivity is not directly proportional to the percentage of an element added to pure iron; the first increment produces by far the greatest effect. Thus the addition of one per cent of nickel to pure iron nearly doubles the resistivity; on increasing the amount of nickel contained, from ten per cent to 20 per cent, the resistivity increases only in the ratio of 40 to 35.

The increased resistivity produced by alloying iron with another metal is not due to the greater resistivity of the added metal. On the contrary, an alloy of very high resistivity can be produced by adding to iron an element of much lower resistivity than the iron itself. Thus, the resistivity of aluminium is equal to about 2.2, while that of iron is equal to about ten; an alloy of iron with 5.5 per cent of aluminium has a resistivity equal to 70. In fact, the resistivity of an alloy appears to have no connection with the resistivities of its constituents.

Table I gives the resistivities of a number of composite alloys of iron. In all cases the resistivity is high, in some instances remarkably so. Thus, an alloy containing 69.40 per cent of iron, 1.18 per cent of carbon, 25.00 of silicon and five per cent of manganese, has a resistivity equal to 97.5 microhms

TABLE I — *Resistivities and Temperature Coefficients of Composite Alloys of Iron*

Percentage Composition	Resistivity in microhms per cm. cube	Temperature coefficient
Fe, 99.89; C, 0.028; Si, 0.07; S & P 0.009 (pure Com. Iron)	10.47	0.006
" 96.59; " 0.59; Cu, 2.5; Mn, 0.32	13.5	0.00457
" 97.36; " 0.68; " 1.6; " 0.36	13.9	0.00418
" 95.93; " 0.17; " 2.9; " 1.00	16.2	0.00366
" 95.26; " 0.04; " 3.7; Al, 1.00	20.8	0.00280
" 93.77; " 0.48; " 2.0; W, 2.00 Cr, 1.75	31.6	0.00204
" 94.26; " 0.22; Al, 5.5; Si, 0.2	74.6	0.00063
" 97.50; " 0.50; Ni, 1.00; Mn, 1.00	28.6	0.00150
" 79.70; " 0.80; " 14.50; " 5.0	83.0	0.00109
" 75.40; " 1.00; " 19.00; " 5.0	90.6	0.00104
" 69.40; " 1.18; " 25.00; " 5.0	97.5	0.00085
" 67.48; " 0.70; " 31.00; " 0.82	86.5	0.00090
" 67.90; " 0.60; " 30.00; " 1.50	89.0	0.00077

per centimeter cube, a value nearly ten times as great as that of pure iron, more than three times that of German silver, and more than twice that of platinoid. Its temperature coefficient (i.e. the increase in resistance per degree C. rise of temperature for each ohm of its original resistance) is fairly small, being equal to 0.00085, while that of copper is equal to 0.004, that of German silver is equal to 0.002, and that of platinoid is equal to 0.0002. The above alloy is easily drawn into wire; it appears to undergo but little change in heating and is not an expensive produce. Another alloy, containing 15 per cent of nickel and five per cent of manganese, has already been put on the market; it was originally called *resista,* but is now known as *rheostene.* It has a resistivity equal to 83 microhms per centimeter cube, and a temperature coefficient of 0.00109. Six years ago the whole of the resistance coils used in the electric installation and lecture theater at the Royal College of Science, Dublin, were replaced by coils of rheostene, and up to the present no depreciation has been noticed. In certain circumstances, however, thin rheostene wires become brittle and perish.

In all cases annealing reduces the resistivities of iron alloys. A rod of one particular alloy, containing 14 per cent of nickel, five per cent of manganese, and two per cent of aluminium, had a resistivity of 89 microhms per centimeter cube before annealing; while the same specimen, after annealing, had a resistivity of 48 microhms per centimeter cube.

The presence of carbon in composite alloys of iron has a marked effect on the resistivity. The curve —·—·—·— (Fig. 1) marked Mn refers to a manganese alloy rich in carbon, while that marked *Manganese* (Low "C") refers to an alloy poor in carbon.

We are unable to give a complete physical explanation of the results described above. At present the mechanism of electrical conduction is unknown, and therefore the peculiarities exhibited by alloys can scarcely even be made the subject of speculation. We have found, however, that certain general laws may be formulated. For small percentages of an added element, the change in the resistivity is roughly proportional to the percentage of the element added. Thus, from the experimental data given above, we may calculate the increase in the resistivity produced by the addition of one per cent of various elements, and so obtain

the figures in the first column of Table II. The second and third columns give the specific heats and the atomic weights of the various added elements.

TABLE II

Added element	Increase of resistivity for 1 per cent of added element	Specific heat of added element	Atomic weight of added element
Tungsten . . .	2	0.035	184
Cobalt . . .	3	0.107	59
Nickel	3.5	0.109	59
Chromium . . .	5	0.1(?)	52
Carbon	5	0.160*	12
Manganese . . .	8	0.122	55
Silicon	13.13	0.183	28
Aluminium . . .	14	0.212	27

* Specific heat of carbon in the form of graphite.

From this table it will be seen that the increase in the resistivity produced by the addition of one per cent of an added element is roughly proportional to the specific heat of the added element, and inversely proportional to the atomic weight of the latter. Thus, one per cent of aluminium added to iron produces an increase in the resistivity which is seven times as great as that due to the addition of one per cent of tungsten; the ratio of the specific heats of aluminium and tungsten is equal to 6.07.

We have also found that the electrical conductivities of these alloys go hand-in-hand with their thermal conductivities, a result which seems to show that, in a metal, electrical conduction and the conduction of heat are closely related phenomena.

In the determination of the magnetic properties of these alloys complete B and H curves were obtained for nearly every specimen, the maximum value of H being 45 C. G. S. units. The specimens have been made in the form of rods about a meter long and half a centimeter in diameter, the magnetometer method was necessarily employed. The rod under test was supported, in a vertical position, within a magnetizing solenoid about 120 centimeters long; the upper pole of the rod was placed at a horizontal distance of about 45 cms. from the magnetometer needle. The direct effect of the solenoid on the magnetometer

needle was neutralized by a compensating coil in the main circuit, while the magnetizing effect of the vertical component of the earth's field was neutralized by a small independent current circulating through a single layer of wire wound round the solenoid. The value of the earth's horizontal component was accurately determined, and checked from time to time during the course of the experiments.

The permeabilities obtained for a number of alloys can be

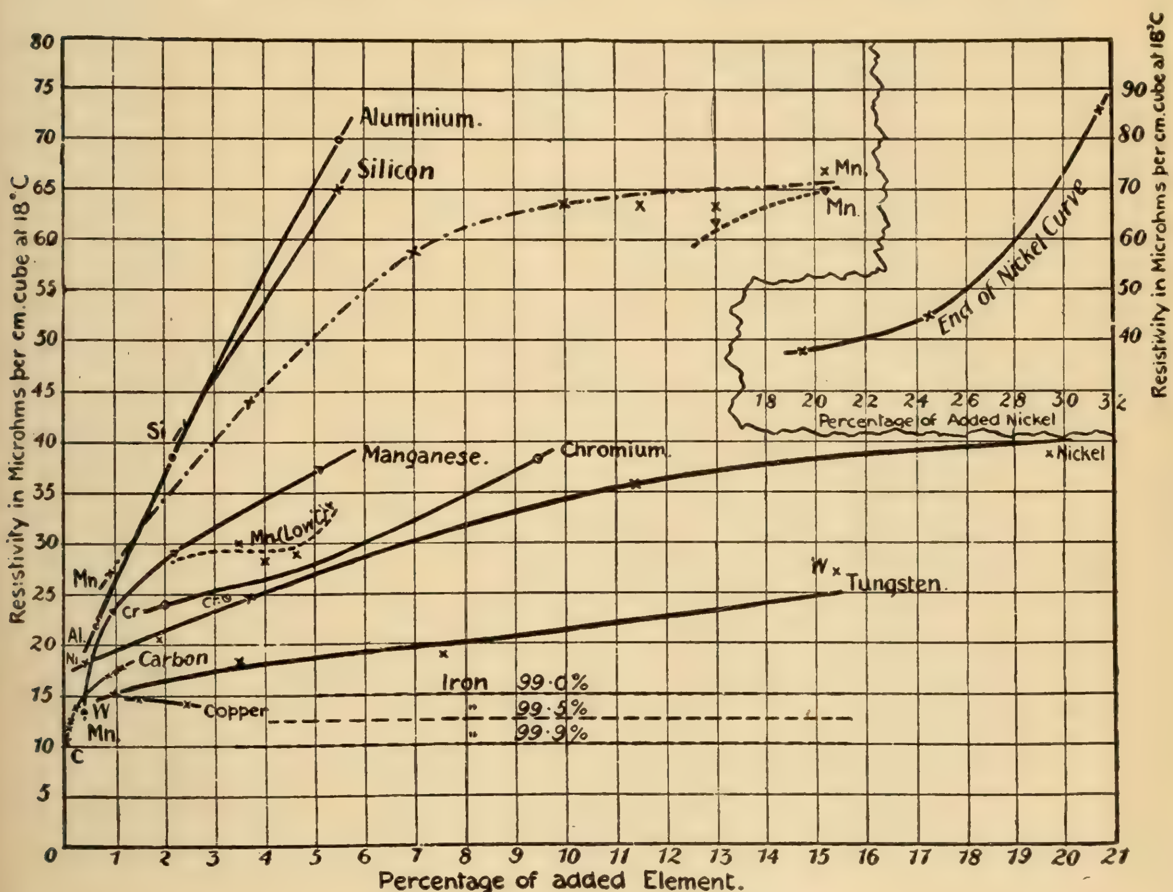

Fig. 1.—Resistivities of Alloys of Iron.

seen at a glance on referring to Fig. 2. The curve for nickel is particularly noteworthy. A small percentage of nickel scarcely affects the permeability, but if the percentage added is increased, a sudden fall in the permeability occurs when about four per cent is reached, the alloy then becoming very feebly magnetic. A further increase in the percentage of added nickel produces little effect until about 25 per cent has been added, when the permeability rises somewhat rapidly.

The first part of the manganese curve resembles the first part of the nickel curve, but the permeability subsequently falls to a lower point, becoming practically equal to unity for a 12.5 per cent alloy of manganese. This alloy is therefore non-magnetic.

A remarkable feature in the magnetic properties of manganese steels is the part played by the presence of carbon in the alloy. In low manganese steel, i.e. when the manganese does not exceed three or four per cent, high carbon reduces the permeability; but in high manganese steels, i.e. when the manganese in the alloy exceeds ten per cent, an increase of carbon raises the permeability. The hardness of the manganese steels, as tested with the file, precisely agrees with their relative magnetic conditions, the steels with the smallest permeability being invariably the hardest.

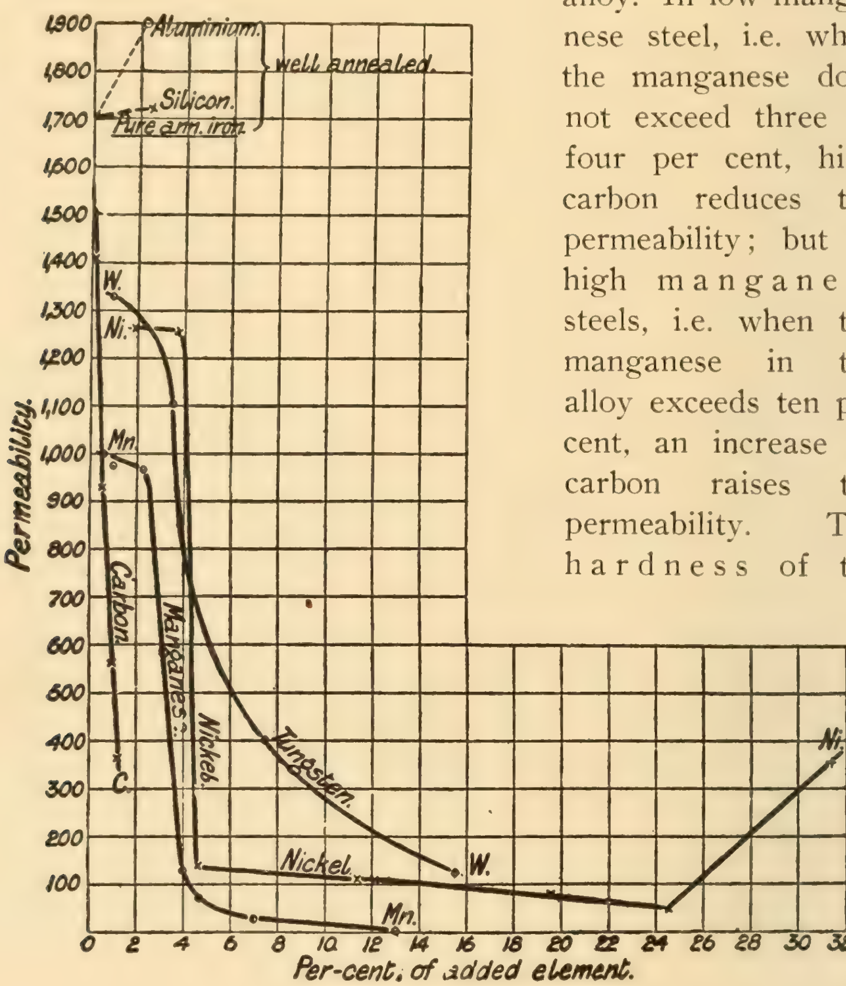

Fig. 2.—Permeabilities of Some Alloys of Iron.

Annealing produces marked effects on the permeability of iron alloys. Thus, an alloy containing 8.9 per cent of chromium and 3.1 per cent of manganese is highly magnetic when annealed but practically unmagnetic when unannealed.

Table III gives particulars of a number of practically non-magnetic alloys of iron. From this it will be seen how remarkable are the magnetic changes produced in certain alloys of iron by the addition of a comparatively small quantity of another element. Thus the high-nickel steels are fairly magnetic, but the

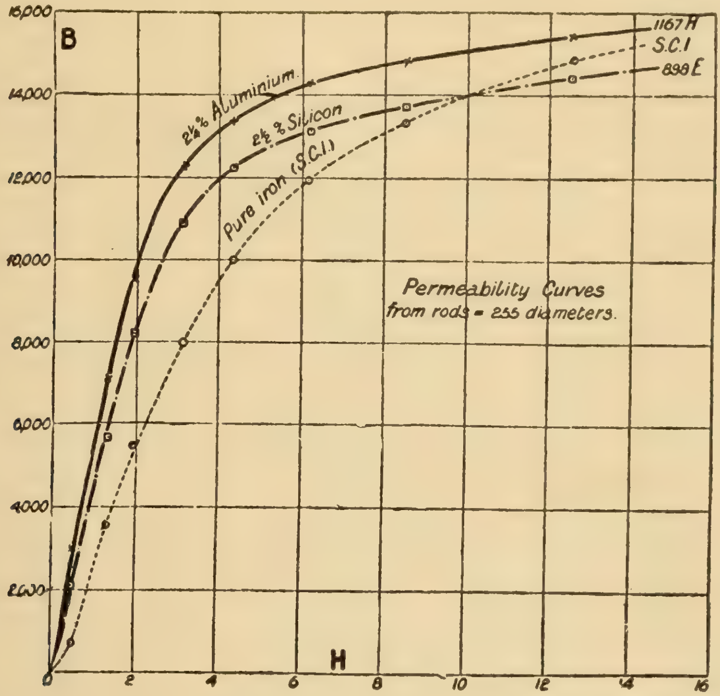

Fig. 3.— B. H. Curves for Pure Iron (S. C. I.) and Alloys Containing Aluminium and Silicon.

addition of five per cent of manganese renders them completely non-magnetic albeit a five or even eight per cent, manganese steel becomes non-magnetic on the addition of two and one-half per cent of nickel.

The extreme hardness of the manganese steels has prevented the general use, but an iron alloy containing 1.4 per cent of carbon, 10.25 per cent of manganese, and nine per cent of nickel is practically non-magnetic, and yet can be readily machined. Non-magnetic steels ships would be a great advantage in navigation, and these could now be made if the cost were not prohibitive.

Unfortunately, many of the above non-magnetic alloys rust badly when exposed to moisture.

Not only is it possible to obtain magnetic alloys of iron, but we can obtain alloys which are much more magnetic than the purest iron. In Fig. 3 the B. H. curves marked pure iron

(S. C. I.) refer to the Swedish charcoal iron, in the same figure are included curves for alloys of iron, containing respectively 2¼ per cent of aluminium and 2½ per cent of silicon. Both these curves lie well above that for pure iron for moderate values of H. The curve for the aluminium alloy remains above that for pure iron throughout the whole length.

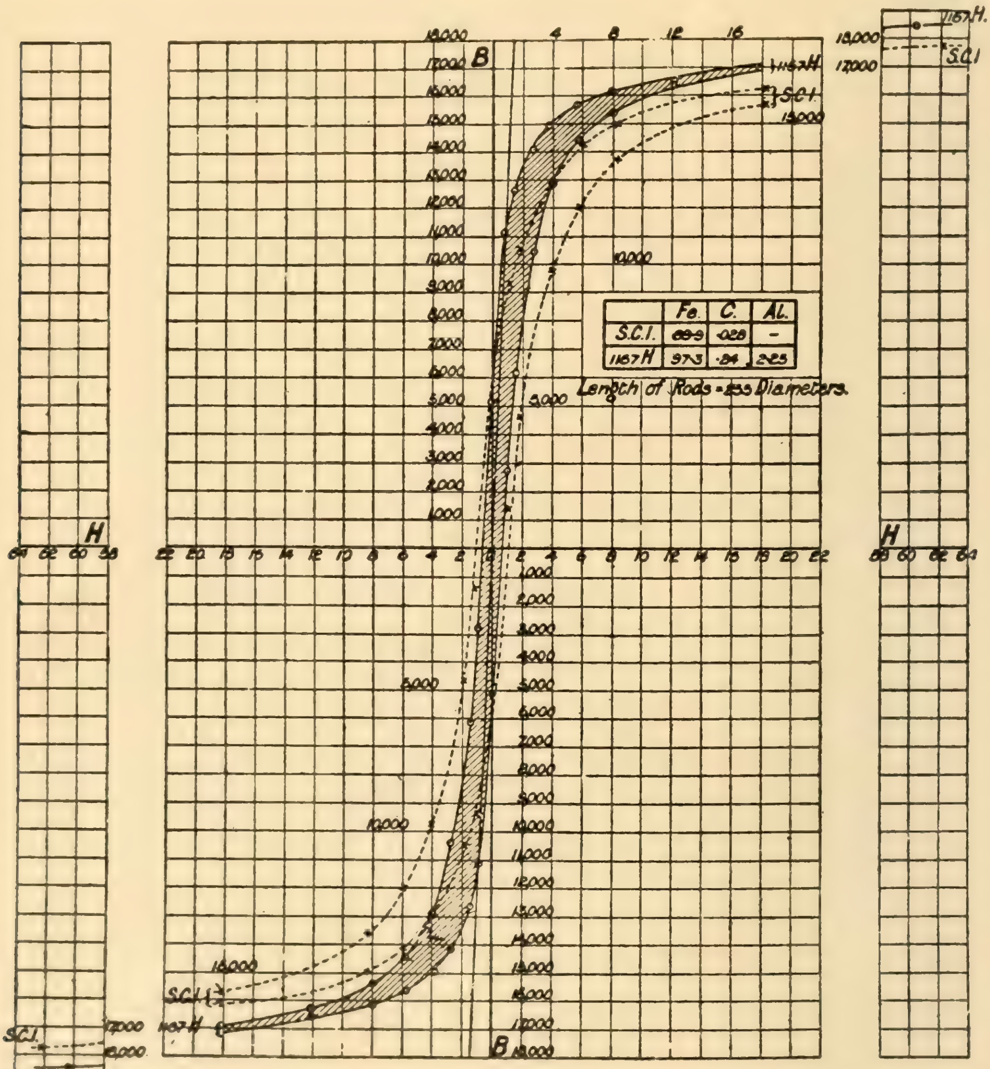

Fig. 4 Complete Magnetic Cycles for Pure Iron (S. C. I.) and an Alloy or Iron Containing 2½ per cent of Aluminium.

ABSTRACTS *

(*From Recent Articles of Interest to the Iron and Steel Metallurgist*)

The Variation in Structure and Tests of Steel. A. Campion. "The Journal of the West of Scotland Iron and Steel Institute," January, 1904. 3,120 w., numerous photomicrographs. — The author gives the results of an investigation which he conducted in order to ascertain how the structure and properties of a single sample of metal can represent the structure and properties of the whole piece. He concludes as follows:

"The results which we have given show very plainly that in the case of sections of steel of small mass and regular shape, the structure, as exhibited by the microscope, shows but little variation at different parts of the piece, provided it has been subjected to the same treatment throughout. Round bars of large diameter of rolled material, and forged material for axles and spindles may exhibit considerable differences of structure, between the outside and central portions. The differences, however, are (excepting in cases where the material has been specially treated) very little if any greater than those obtained in analytical and mechanical testing. Material in irregular shapes and unequal masses exhibit very considerable differences as regards both analyses and structures in the various portions of the section.

"Such materials as axles and tubes of guns, which have

* Note. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H", $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

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been subjected to special treatment, as oil quenching and tempering, show the effects of the treatment in a marked degree on the outside portions. The carbide areas gradually diminishing in volume towards the center where the structure (except in material of very small diameter) exhibits that of the material before treatment.

"Although a large number of etching media have been suggested by various operators, and every one has his own pet solution, they all give identical results when used under suitable conditions. The structure of some steels may be much more clearly developed by one method than another, but the ultimate result, as far as size of grain and constituents present, is the same in all cases." **No. 167.**

Chrome Steel. Leon Guillet. "Revue de Métallurgie," Vol. I, No. 3. — Two series of steels have been examined, one comparatively low in carbon, and the other containing about 0.8 per cent carbon. Of the first series, the contents of carbon and chromium with the corresponding results obtained from tensile, shock, and hardness tests are included in Table I, following:

TABLE I — *First Series*

Carbon per cent	Chromium per cent	Tensile				Frémont Test, Kilogram-meters	Hardness Brinell
		Maximum Stress	Elastic Limit	Elongation per cent	Reduction of Area per cent		
0.043	0.903	35.4	22.6	25.0	74.9	32	95
0.058	1.207	56.4	42.9	14.0	58.2	20	134
0.214	4.502	60.3	56.5	15.5	62.1	25	160
0.071	7.835	150.6	99.7	3.5	7.5	9	364
0.114	9.145	143.1	129.6	2.0	4.5	10	351
0.154	10.136	139.3	101.7	1.0	0	9	387
0.142	13.603	86.6	50.4	1.5	7.5	3	277
0.382	14.522	100.1	89.3	2.0	7.2	3	241
0.210	22.060	65.7	89.5	13.0	24.5	2	170
0.244	25.306	57.3	40.1	17.5	52.5	1	179
0.464	31.746	57.5	43.3	12.0	50.4	1	156

From the tensile results low carbon chrome steels may be classified into three groups — (1) from 0 to 7 per cent chromium, representing steels of similar properties to ordinary carbon steels, but of higher breaking loads, the latter increasing with a rising chromium; (2) steels containing from 7 to

22 per cent chromium, which has a high breaking load, high elastic limit, low extension, and low reduction of area; (3) steels exceeding 22 per cent chromium, of relatively low elastic limits, low breaking loads, and with elongations and reduction of area relatively high. Steels of this class, from their tensile results, approach those of high nickel or manganese content. The results obtained from the Frémont test also permit of the steels being divided into three groups — (1) nonfragile steel containing from 0 to 7 per cent chromium; (2) steels containing from 7 to 22 per cent chromium, which offer an average resistance to shock; and (3) fragile steels in which chromium exceeds 22 per cent. If these results are compared with the tensile ones it will be noted that steels of the third class, which are very fragile, show in the tensile test comparatively high elongations and reduction of areas. This clearly demonstrates the fact that shock tests give results other than those furnished by the tensile test. Second series. — The results obtained from this series are embodied in Table II, above. The tensile tests divide the carburized chrome steels into three classes — (1) steels containing from 0 to 5 per cent chromium, possessing similar properties to ordinary carbon steel, but with relatively higher elastic limits and breaking loads, these values increasing with a rising chromium; (2) steels of 5 to 18 per cent chromium, possessing high breaking loads accompanied by relatively low elastic limits; (3) steels exceeding 18

TABLE II — *Second Series*

Carbon per cent	Chromium per cent	Tensile				Frémont Drop Test, Kilogram-meters	Hardness Brinell
		Maximum Stress	Elastic Limit	Elongation per cent	Reduction of Area per cent		
0.965	0.519	109.2	79.1	2.5	16.6	3	310
0.973	0.986	131.8	131.8	3.5	7.5	2	332
0.887	2.141	139.3	97.9	2.5	0	3	364
0.789	4.570	133.3	84.4	3.0	7.5	3	293
0.840	7.279	124.3	60.2	3.0	17.6	5	377
0.751	9.376	94.1	79.1	13.0	0	3	387
0.961	11.521	132.5	79.1	5.0	14.7	1	321
0.741	14.538	120.0	65.5	1.0	0	6	477
0.903	18.650	128.0	128.0	0.5	0	2	387
0.820	26.541	59.3	48.9	10.0	45.1	1	170
0.916	32.560	67.8	56.4	13.0	40.8	2	187
0.838	36.340	—	—	—	—	2	228

per cent chromium of low elastic limits, and breaking loads accompanied by high reductions of area. The Frémont test shows all the steels to be fragile; it may, however, be noted that the 14 per cent chromium alloy is less fragile than the others. The hardness test indicates two classes — (1) hard steels containing from 0 to 18 per cent chromium, and (2) steels of average hardness exceeding 18 per cent chromium. Finally, a correlation of the micro-structures with mechanical properties show that untreated chrome steels may be grouped into three characteristic classes — (1) steels of similar structures to carbon steels. These steels have a high elastic limit and maximum stress, both of which increase with the content of chromium, whilst the extensions and reduction of areas remain high, irrespective of the amount of chromium. The hardness increases with the content of carbon and chromium, and is always higher than ordinary steels of the same carbon content. (2) Steels of a martensitic structure. These steels when highly carburized apparently show more troostite than martensite. They have high breaking loads and elastic limits, low elongations, and reduction of areas. Members of this class are hard, and when the content of carbon is low they present an average resistance to shock. (3) Steels of special structures showing numerous white areas of double carbide of iron and chromium. These steels have a breaking load and elastic limit relatively low, but show comparatively high elongations and reductions of area. They are very fragile and of feeble hardness. "The Engineering Review," May 1, 1904. No. 171. B.

The Plastic Yielding of Iron and Steel. Walter Rosenhain. 15,200 w., illustrated. Paper read at the May (1904) Meeting of the Iron and Steel Institute. — The first point dealt with in connection with these new observations is the explanation of the "curved" slip-bands in iron and mild steel. The conception that the curvature of slip-bands might be accounted for by minute stepping of the lines is already mentioned in a previous paper. In the present paper, however, new micrographic evidence in favor of this hypothesis is advanced and a fresh line of evidence is brought forward by the examination of slip-bands in iron under the highest power

available with oblique light. Such examination is shown to resolve the slip-bands which appear as continuous but curved lines under vertical light, into discontinuous lines whose curvature is much less apparent. The dark gaps in the slip-bands as seen under such illumination are ascribed to minute steps along gliding surfaces having a different orientation. The "curvature" of slip-bands in iron having been shown to be probably due to a multitude of minute steps, a reason is suggested why this stepping should be so marked a feature in iron, while it is so comparatively rare in certain other metals. This reason is that the ferrite crystals in ordinary iron and steel are formed by crystallization from a solid solution, while the ordinary crystals of lead, for instance, are formed by crystallization from a true liquid. By producing lead crystals in strained and annealed lead, and showing that the slip-bands in these crystals also commonly assume stepped or "curved" forms, the probable truth of the suggested explanation is demonstrated.

The truly crystalline character of slip-bands is further demonstrated in a novel manner by the observation of slip-bands in iron following and revealing the gliding planes of twin crystals.

Finally, the view has been advanced that the strength of inter-crystalline cohesion in pure metals and certain forms of alloys is due to the interlocking of the skeleton arms which the crystals develop during their first formation. According to this view, the inter-crystalline boundaries take the form of regions of mixed orientation, and certain consequences are to be deduced from this consideration. It is argued that, since a region of mixed orientation must offer greater resistance to slip than a region of uniform orientation, the inter-crystalline boundaries form a network of cells upon which the true resistance of the metal depends. Plastic deformation sets in when these cell-walls begin to give way; in doing so they will carry with them the less resisting masses of the crystalline grains. In this way the observed relation between slip-bands and inter-crystalline boundaries is explained. Observations of a frequent doubling of the inter-crystalline boundaries between ferrite grains in pure iron and the "bordered boundaries" and "spines," discovered by Osmond, Frémont, and

Cartaud, in strained metal are adduced as further evidence in support of this view of the structure of inter-crystalline boundaries.

The bearings of this theory on the influence which casting temperature exerts on the structure and strength of castings is discussed, and the effect of mechanically disturbing the crystallization of a metal is considered — first, in reference to the effect of forging iron and steel, and, finally, an experiment is described showing the effect of mechanical disturbance during the act of crystallization upon the inter-crystalline boundaries of ordinary lead. **No. 168.**

The Briquetting of Iron Ores. Alois Weiskopf. "Engineering Press Index Review," April, 1904. 4.875 w. — The object of this article is to review the question of the briquetting of iron ores in a finely divided state.

The author at first sets forth the difficulties which have hitherto presented themselves in treating grains or dust by means of the blast-furnace. He then shows the necessity of enriching ores containing little metal by special processes and comes to the conclusion that as these processes of enriching necessitate the pulverizing of the ore beforehand, it is necessary before submitting it to the blast-furnace, to agglomerate it into a special shape so that it may not injure the furnace. The author then discusses the conditions which should be fulfilled by good briquettes and classifies the processes previously employed, which, in short, we may sum up as follows:

1. Briquettes made with agglomerating material.
2. Briquettes made without agglomerating material.

After having compared these two principal groups and their subdivisions the article treats of the processes which are based on the principle of employing agglomerating material, indirect agglomerating material, and material without any agglomerant. The author describes then two processes which so far have given the best results — that of Edison and that of Grödal-Dellwick.

The first of these processes belong to category I. The ore after having been enriched by magnetic separation is mixed with resin and put into a special furnace at a temperature of from 200° to 300° C. The author, relying on results

of analyses, declares the product obtained to be of good quality but that it does not give in practice all the results desirable.

The Grödal-Dellwick process belongs to group II, the molding of the briquettes being made without agglomerating material at a high temperature and under strong pressure. Even this process can give good results only on condition of treating with good magnetic ore.

In concluding, it is stated that the question of the agglomeration of fine ores is far from being solved in practice or in theory. What is required is an agglomerating material permitting the economical manufacture of the ore, as the expense for the processes at present employed surpass the cost price of the ores themselves. After going into calculations, the author expresses the opinion that the difficulties hitherto met with should not tend to discourage one, and that for his own part he is convinced of ultimate success. **No. 169. C.**

Pyrometers Suitable for Metallurgical Work. 24.000 w., illustrated. — Report of a committee appointed by the Iron and Steel Institute and consisting of R. A. Hadfield, J. E. Stead, and B. H. Brough. Invitations were sent to all the leading makers to exhibit pyrometers at the May (1904) meeting of the Institute and to furnish brief descriptions of them. In the present report the following instruments are described:

(1) Baird and Tatlock pyrometer; (2) Bristol's recording air pyrometer; (3) Callendar and Griffith resistance thermometer; (4) Le Chatelier pyrometer; (5) Mesuré and Nouel optical pyrometer; (6) Roberts-Austen recording pyrometer; (7) Rosenhain and Callendar pyrometer; (8) Siemens electrical pyrometer; (9) Siemens water pyrometer; (10) Uehling pneumatic pyrometer with Steinbart automatic recorder; (11) Wanner optical pyrometer; (12) Wiborgh's thermophone; (13) Zaubitz pyrometer.

In conclusion a list of patents relating to pyrometry and a bibliography of the subject are given. **No. 170.**

Microstructure of Some Alloys of Iron. H. C. H. Carpenter. "Technics," May, 1904. 2,800 w., 12 photomicrographs. — The article describes the microstructure of some silicon-iron and aluminium-iron alloys, whose magnetic prop-

erties had been investigated by Dr. Glazebrook. They contain respectively 2.25 per cent Al and 2.50 per cent silicon with about 0.20 per cent of carbon, and only traces of manganese, sulphur and phosphorus. **No. 172. C.**

Modern Methods of Handling Iron Ore from Minnesota Mines to Pittsburg Furnaces. C. H. Wright. "Engineering News," May 5, 1904. 3,520 w., illustrated. — An interesting article by the chief engineer of Brown Hoisting Machinery Co. **No. 173. A.**

Segregation and Diffusion in Steel. B. F. Weston. "Iron Age," May 19, 1904. 3,120 w. — The author explains the occurrence of segregation and diffusion and gives many instances of the segregation of carbon, silicon, manganese, phosphorus and sulphur in steel. **No. 174. A.**

The Electrical Manufacture of Steel. Gustave Gin. "The Electro-Chemist and Metallurgist," March, 1904. 3,700 w., 6 illustrations. — The author describes his latest process for the production of steel by electrical means, the principle involved being that of heating a thin stream of metal by the passage of an electric current. **No. 175. B.**

Electrically Driven Rolling Mills. Condensed from a paper read at Düsseldorf before the Verein Deutscher Eisenhüttenleute, by H. Koettgen. "The Iron Age," May 19, 1904. 4,400 w., illustrated. **No. 176. A.**

The Manufacture of Hydraulically Forged and Rolled Solid Steel Railway Wheels. Henrik V. von Z. Loss. "The Journal of the Franklin Institute," May, 1904. 3,450 w., illustrated. **No. 177. D.**

A Blast-Furnace Gas Engine Electric Station. Emile Guarini. "The Engineer," (Chicago). 1,100 w., 4 illustrations. — The author describes the installations of the metallurgical power station at Ilsede. The gas used comes from three blast-furnaces, of which the average production is 220 tons of iron per day. Part of the furnace gases are used to

heat boilers furnishing steam for a central electric station having a capacity of 1,830 horse-power. The energy there generated is used in the power house of neighboring iron mines and in the rolling mills at Peine, where the iron produced at the Ilsede furnace is worked up. The blast-furnace gas is also used to operate two blowing engines of 500 horse-power each, which replaced the steam engines formerly employed. **No. 178. A.**

The Use of Steel in American Lofty Building Construction. B. H. Thwaite. Paper read at the May (1904) Meeting of the Iron and Steel Institute. 1,680 w., illustrated. **No. 179.**

Modern Blast-Furnace Construction (Gesichtspunkte beim Bau moderner Hochöfen). E. Lamoureux. " Stahl und Eisen," April 1, 1904. 3,000 w. — A review of modern furnace construction comparing European and American practice. **No. 180. C.**

Gas Losses in Open-Hearth Furnaces (Die Gasverluste der Diemensöfen). Fr. Schraml. " Stahl und Eisen," March 15, 1904. 1,800 w. — A description of the various sources of losses of gas in open-hearth furnaces, and of improvements in the construction of valves. **No. 181. C.**

The Construction and Operation of Wire Rod Rolling Mills (Über Bau und Betrieb von Drahtwalzwerken). J. Hubers. " Stahl und Eisen," March 15, 1904. 2,000 w. — The author describes different arrangements of rolls for continuous mills. **No. 182. C.**

The New Wire Rod Rolling Mill at Differdingen (Die neue Drahtwalzwerksanlage in Differdingen). K. Gruber. " Stahl und Eisen," April 1, 1904. 2,000 w., illustrated. — The author describes a rolling mill driven by a gas engine run by blast-furnace gas. **No. 183. C.**

The Production of Steel Without the Use of Scrap or Ore (Stahlerzeugung ohne Verwendung von Alteisen und

Erz). Oskar Goldstein. "Stahl und Eisen," March 15, 1904. 1,000 w. — The author describes a combined converter and open-hearth process used in Mexico. **No. 184. C.**

"The Foundry." — The May (1904) issue of "The Foundry" contains the following articles of interest:

"Foundry of the American Locomotive Works, Schenectady, N. Y."

"Green Sand Bottoms and Sound Castings." By H. L.

"Education in the Foundry." By Jas. A. Murphy. (Paper read before the Erie Foundry Foremen, March 19, 1904).

"Foundry Costs. Their Analysis and Reduction." By Henry Hess. (Paper read before the Engineer's Club of Philadelphia, Pa., October 17, 1903.)

"Some Uses for Old Crucibles." By J. F. Buchanan.

"A Glossary of Metal Founding Terms." By A. E. Fay.

"Molding Machines." By George C. Nielsen. (Paper read before the Chicago Foundry Foremen's Association.)

"A Molding Sand Difficulty."

"Testing Cast Iron." By Dr. Richard Moldenke. (Read before the New England Foundrymen's Association, February 10, 1904.) **No. 185. A.**

"The Foundry." — The June (1904) issue of "The Foundry" contains the following articles of interest:

"Corrosion of Metals" (1,960 w.). By J. F. Buchanan.

"Pig Iron Warrants System and the Foundryman" (1,568 w.). By Howard M. Hooker.

"The Use of Cast Iron Borings" (1,086 w.). By A. E. Outerbridge, Jr.

"Lining and Fluxing a Cupola" (784 w.). By Albert E. Bolton.

"Specifications for Cast Iron and Finished Castings" (1,086 w.). By Richard Moldenke. **No. 186. A.**

"**American Machinist.**" — Recent issues of the "American Machinist" contain the following articles of interest:

May 5. "A Two-Ton Foundry Ladle."

May 12. "The Effect of Limestone Additions on the Product in Cupola Practice." F. Wust; translated by J. E. Johnson, Jr. (Concluded in May 19th issue.)

June 2. "A Great Feat in Shaft Straightening."

Report of a committee to coöperate in standardizing abbreviations, symbols, productions, etc., in technical papers.

"High Speed Tool Steels." By Walter Brown. **No. 187. A** (each issue).

Aluminium Tin Alloys. E. S. Shepherd. "The Journal of Physical Chemistry." April, 1904. 4,141 w., illustrated. — A description of the constitution and microstructure of alluminium-tin alloys. **No. 188. C.**

Some Statistics of the World's Iron and Steel Industries. William Pollard Digby. "Journal of the Society of Arts," May 6, 1904. 5,610 w. — Contains many statistical tables and diagrams referring to the productions of iron ore, iron and steel in England, Germany and the United States. **No. 189. B.**

EDITORIAL COMMENT

Harry Huse Campbell

Harry Huse Campbell was born in West Roxbury, Mass., on March 10, 1859. He was educated in the public schools and in 1875 entered the Massachusetts Institute of Technology where he graduated in 1879 with the degree of Bachelor of Science in Mining Engineering. In the same year he entered the employ of The Pennsylvania Steel Company at Steelton, Pa., and has been with that company ever since in the following capacities: 1879, Learner in Bessemer department; 1880, in charge of special steels, Hammer department; 1882, Assistant in Open-Hearth department; 1883, Assistant Superintendent Basic Bessemer department, this being the first time the basic Bessemer process was used in this country; 1884, Foreman in new Open-Hearth department; 1885-1889, Superintendent Open-Hearth department; 1889, Assistant Superintendent The Pennsylvania Steel Company; 1893, Superintendent; 1899, Superintendent and General Manager; 1901, General Manager to date.

Among the most important papers which Mr. Campbell has contributed to the transactions of Technical Societies, the following may be mentioned: "The Physical and Chemical Equation of the Open-Hearth Process," "Transactions American Institute Mining Engineers," Vol XIX; "The Open-Hearth Process," a paper of 167 pages presented at Chicago, 1893, meeting of the same Institute; "The Physical Properties of Nickel Steel," and "Specifications for Structural Steel," both papers read before the American Society of Civil Engineers in 1895. In the same year appeared the first edition of Mr. Campbell's book on "The Manufacture and Properties of Structural Steel," and in 1903 a revised and greatly enlarged edition of this book was published under the title of "Manufacture and Properties of Iron and Steel." The following year (1904) a third and again revised edition was published.

The subject of this sketch and his work are so well known to our readers as hardly to call for any comment on our part.

The mere mention of his steady rise, step by step, in the company which employed him upon the completion of his technical education, affords a striking testimony of recognition by the employer of the worth of the employee. To the young man just entering upon his life's work a record like this should be an inspiration.

To the mastery of his art acquired during 25 years of uninterrupted and close association with steel making in its various phases Mr. Campbell adds a mind of exceptional lucidity and a power of expression that but few possess. His literary contributions to the metallurgy of iron and steel are in consequence of a very high character, being full of the accurate observations and reasoning of a keen observer and of a logical mind. Among his practical contributions to the metallurgical art it will suffice to mention the invention of the first tilting open-hearth furnace and the production of low phosphorus acid open-hearth steel by the transfer process, a steel which is being used in the new East River bridge.

The Bray Semi-Continuous Mill for Sheets and Tin Plates

The modern three-high plate mill, the looping and continuous rod mills, the continuous billet and sheet bar mills and the modern rail mill, with their enormous daily tonnages achieved with almost infinitesimal manual exertion, are all old stories. As they were developed by the pioneers the iron trade accepted them with nonchalance, seeing no cause for more than momentary congratulation. Their method of attack appeared so natural that their advent produced little supprise, while the ponderous machinery required and the large tonnage for which markets had to be found removed cause for the suggestion that they should have been developed earlier in the history of the steel industry.

Yet with all these lessons there has been little chafing at the continuance of methods for the rolling of sheets and black plates for tinning which are of the crudest and most laborious character. In ordinary rolling for tin plate purposes, if a 10-inch bar is employed, its thickness is reduced to about one-twenty-fourth the original thickness, and this requires four heatings, from two to five passes only being given after each heating. Citing an instance, in the production of black plate for 100-pound tin plate, the required gauge is between 30 and 31; the finished

product of the hot mill is a pack of eight thicknesses, trimmed and sheared to two packs each 20 by 28 inches, weighing altogether $28^4/_7$ pounds, and for this purpose two bars, 20½ inches long, and with such a thickness as to make the weight of each about 16 pounds whether the width is 8, 10 or 12 inches, must be handled first singly and then as a pack, about sixty times, and the labor cost until the 18 per cent reduction this year has been $12.37 per gross ton, or 16 cents for the double pack which is the product of these sixty odd handlings. The bare labor cost of the reduction is more than double the total cost of converting a ton of pig iron into 4 × 4 billets, and much more than the total cost of reducing these billets to wire rods, while it is from 25 to 50 times as great as the labor cost of reducing slabs to quarter-inch plates on modern three-high plate mills.

It is therefore extremely gratifying to note that a practical innovation has at last been introduced. Since last fall the semi-continuous mill designed by C. W. Bray has been in successful operation at the Monongahela tin plate works, and contracts are now being let for a somewhat similar mill to be installed at Sharon for the rolling of sheets. Partly from circumstances wholly apart from the technical problem involved, and partly because the tin plate business involves a much narrower range of sizes and gauges, the first adaptation of the Bray idea was to a tin mill, but once successful it is believed the saving per ton will be greater on sheets than on tin plate.

The plant at the Monongahela works consists of a continuous heating furnace, five stands of roughing rolls, with tables, an automatic matcher, two stands of finishing rolls and an automatic doubler. Two heated bars having been successively roughed are matched and the pair is then further reduced, being finally doubled into a pack of four. This work, done with one heating, is ordinarily accomplished with two heatings. The balance of the work is carried on under the old style, the packs of four being heated, rolled, doubled, heated and again rolled into a pack trimming into two packs of 20 by 28 inches. Thus substantially half of the former hand labor is dispensed with. In the case of sheets, the work is started with a somewhat heavier bar, and six roughing passes will be given, with two finishing, and the resultant material, having to be finished into heavier gauges, will receive but one heating and rolling by hand, so that roughly

the Bray mill will in the case of sheets dispense with two-thirds the labor ordinarily accomplished by hand.

It might be supposed that the principal obstacles encountered in the somewhat protracted experimental stage which preceded commercial success lay in the rolling proper. This was not the case. It was a matter of no great difficulty to have the material enter the first and succeeding passes properly. Parenthetically it should be noted that the mill is fundamentally a tandem rather than a continuous mill in the strict sense. One chief difficulty was in the heating. In the ordinary process the furnace is but ill adapted to the awkward method of operation, which requires the withdrawal of heated material intermittently with the insertion of material at no more than a black heat. The skill of the heater surmounts most of the difficulty, and what lack of regularity remains the roller takes care of. The automatic mill recognizes no such demands, and it therefore became necessary to heat the bars with a perfection and regularity never attained by hand work. As the finish required does not allow the steel to be brought to the ordinary scaling temperature the problem is difficult, since every part of the bar must be brought absolutely up to a limit, and that limit is a low one. Any irregularity would affect the reduction in different parts of the bar and prevent regular progress through the successive passes. The furnace had to be rebuilt several times before regularity and absence of scaling was attained. The automatic matcher, which simply places one piece evenly on another, also presented some difficulty, as did the doubler.

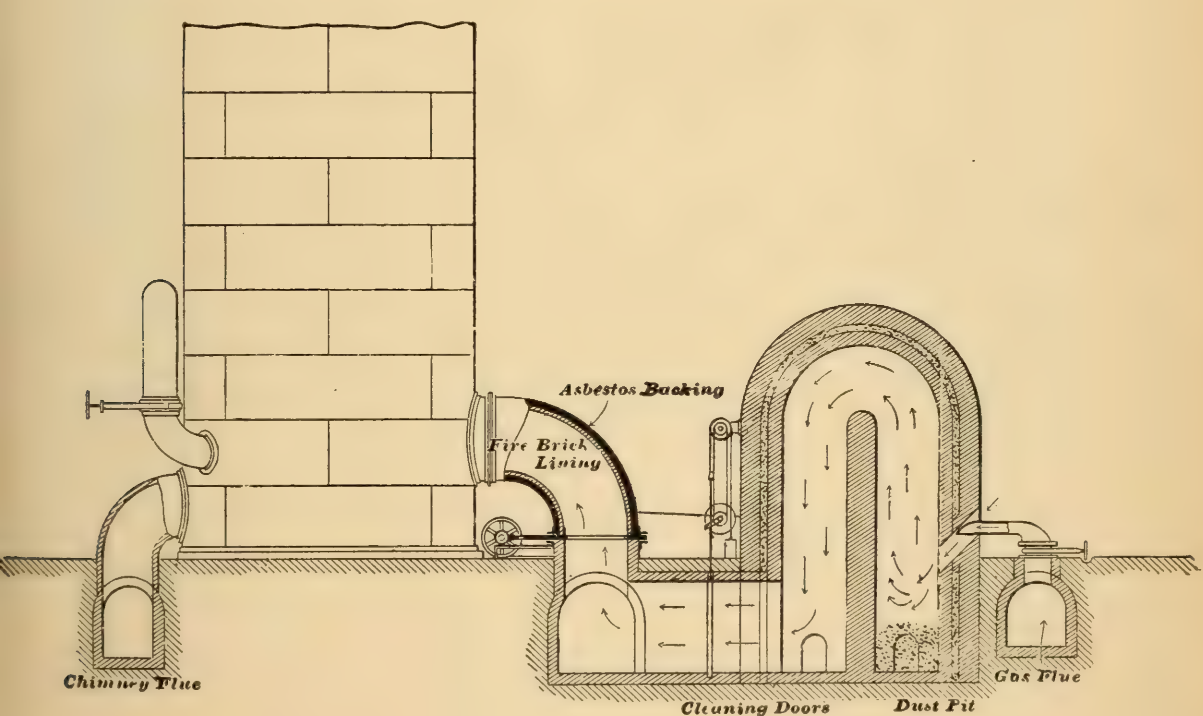
When the low temperature at which the work is done is mentioned, it will be seen how rapidly all the operations must be performed to permit of seven or eight passes being given before the steel is cold. It is well understood that even in the ordinary operation the steel loses more heat to the rolls than to the air, the greater conductivity of the former more than making up for the much shorter period of contact. As a consequence, the principal saving in heat loss, when double work is to be done with a heating, must be purely of that part of the heat loss which is the smaller. However, it is probable that a reduction has been effected also in the quantity of heat lost to the rolls. The problem here presented is an interesting one. The roll may be compared to a cistern with a constant level yet constantly re-

ceiving and losing water. The hotter the roll, the faster it loses heat and the less each piece loses to it. With each stand of rolls doing continually the same work it is possible to work with the rolls a little hotter than in the ordinary operation, where the work is more varied, and the heat contributed may come therefore from a greater number of pieces.

So far as we know, no manufacturer, other than the American Sheet and Tin Plate Company, which controls both the Monongahela and Sharon works, has done any experimenting of late along this exact line. Mr. Bray, the inventor, is chief mechanical engineer of the company. How far the ideas are protected by patents cannot be known until these have been issued. So far but one, and it is a very general one, has come out. Nothing has been heard for some time of the Norton mill, at Chicago, which aimed to largely eliminate hand labor by entirely different means. The Norton mill is a two-high reversing mill, and an ingenious system has been patented by which the tables and rolls are reversed and the screw turned by different amounts for successive passes.

IRON AND STEEL METALLURGICAL NOTES

Blast-Furnace Stoves with Separate Combustion Chamber. — The object of this device, patented by Mr. A. P. Gaines, of Birmingham, Ala., is to provide a combustion chamber, which shall be entirely separate and independent from the stove or regenerative chamber. The separate combustion chamber may be used with two or more stoves at any one time; consequently when one stove is on blast, the other will be on gas, thereby securing continuous passage of gas through the combustion chamber, and maintaining the highest temperature at all times.



The low efficiency of the hot-blast stoves now in general use is due chiefly to incomplete combustion and non heat-conducting dust or dirt carried into the stoves with the gas. This construction, it is claimed, overcomes these objections as in this arrangement the air blast never passes through the separate combustion

chamber, the passage of the gas being continuous, so therefore the temperature is always maintained inside the combustion chamber that will insure complete combustion; as can also the burning of the gas be regulated satisfactorily as it can be watched and tested before admission into stove, which is impossible in the stoves as now constructed. The dust which is held mechanically in the gas is largely precipitated on combustion in the combustion chamber, and therefore in this arrangement cannot be carried into the stove as when the combustion chamber is contained inside of the stove proper. It also follows that having the combustion chamber separate from the stove a very appreciable increase in heating surface will be gained as the space and heavy walls now required for the combustion chamber will be filled with checker work, and as the blast does not pass through the separate combustion chamber, when built independent, it need not be expensive in construction for it will not be necessary to enclose it in an air-tight sheet iron shell; thus the large increase in heating surface is obtained at considerable saving in first cost of construction.

Again, as the repairs on the modern hot-blast stoves are required very largely, if not entirely in the combustion chamber the provision of an independent and separate combustion chamber for each stove, with each combustion chamber connected to two stoves, obviates the frequent withdrawal of the stove from service. When repairs are needed in a combustion chamber in active service the extra combustion chamber can be put in service and there will be no interruption of the service of the gas through the stoves.

The German Steel Syndicate. — The German Steel Syndicate has secured, after long negotiation, the adherence of the Phoenix Company at Ruhrort, the only large concern remaining outside of the combination. The directors of that company were opposed to joining the syndicate, but at the recent annual meeting the stockholders passed, by a large majority, a resolution instructing the directors to make the required agreement. The Steel Syndicate will, therefore, be in practical control of the German trade in finished steel products, as no important mills will remain independent. — "Engineering and Mining Journal," May 19, 1904.

Basic vs. Acid Steel Rails. — Some controversy is going on in England upon the supposed inferiority of rails made from basic steel to those manufactured from Bessemer metal. A prominent firm, Cammell, Laird & Company, some time ago issued a pamphlet in which they endeavored to show that breakages of rails have been much more frequent where basic steel rails are used. Their evidence, however, is not accepted by engineers, and it is pointed out that the use of basic steel for rails is almost universal in Germany, and that no inferiority has been found there, the rails being fully up to the standard. The dispute seems to be more a manufacturer's argument than anything else.

In this country there will soon be an excellent opportunity for testing the relative merits of the different materials. The Tennessee Coal, Iron & Railroad Company is turning out, from its Ensley works, a large quantity of rails made from basic open-hearth steel. These rails will be laid on the Louisville & Nashville and on the Southern railroad, where they will be used side by side with Bessemer steel. Any difference in the wear and strength of the rails will quickly be noted under the best conditions for a test. — "Engineering and Mining Journal," June 2, 1904.

The American Society for Testing Materials. — The Society held its seventh annual meeting at Atlantic City, June 16, 17 and 18, 1904. The meeting was a very successful one both as to attendance and work. A number of valuable papers were read and elicited vigorous and instructive discussions. An exhaustive report of this meeting, including full reprints of the most important papers, will be made a special feature of the August issue of *The Iron and Steel Magazine.*

REVIEW OF THE IRON AND STEEL MARKET

The iron trade has continued on the down grade since our last report. The current bookings of new business by producers has been extremely small, so that they have been rapidly reducing the tonnage of unfilled orders on their books and in many cases have already had to decrease their rate of production. There is nothing in sight for the next two months but a further curtailment of production all along the line.

The culmination of the increase in pig iron production, which started the first of the year, when the annual rate was but a trifle over 10,000,000 tons, came in April when the production was at the rate of about 19,400,000 tons annually. Since early in May there has been uninterrupted blowing out of furnaces, which will likely continue until by the first of August the country will be making pig iron at the rate of about 14,000,000 tons a year. Steel works, both Bessemer and open-hearth, have been closing here and there, while many of those still in operation are running at reduced pressure. Finishing mills are running more and more intermittently.

It requires no diligent search to find the immediate causes of the greatly reduced amount of business offered. There has been almost universal distrust of the permanency of prices, which has already been amply justified by increased weakness in many lines, and actual reductions in the case of others, giving fairly clear indications of a more distinct downward movement to follow. In these circumstances regular consumers delay covering for their ordinary requirements, and those who contemplate strictly new work refuse to put any of their plans into execution. The railroads, ordinarily the great consumers of iron and steel products, are financially in very poor condition to buy, being forced to husband resources which have been made meager by heavy increases in operating expenses and by dividends on rather extensive capitalization. The agricultural classes have been good buyers, but in the case of machinery their purchases have operated to decrease dealers' stocks rather than to bring additional business

to machinery makers. Little more business can now be expected from the agricultural sections until crops have turned out well and have been harvested. Exports of iron and steel products have not furnished as much relief as was hoped they would.

Nothing could be clearer than the resemblance of present conditions in the iron trade to those of twenty years ago. It needed no discernment to discover the exact counterpart, two decades earlier, of the panic of 1893, the five dull years which followed, and the sudden and complete revival of activity in 1899. The parallelism is exact up to the present moment, and the statement is based equally upon a comprehensive study of present conditions as upon the lesson of twenty years earlier, that we shall have continually decreasing activity and falling prices for several months yet, followed by a quiescent period developing, early in 1905, into a moderate degree of activity with steady and slightly advancing prices. The period of moderate and reasonable prosperity to be inaugurated early next year will lack the spectacular features which have characterized the iron trade in recent years, but will afford an equitable and commensurate return for well directed effort and the wise investment of capital.

Pig Iron. — The middle of June saw a collapse of the strike of the Masters' and Pilots' Association on the Lakes and the true inauguration of ore shipping. To that time there had been brought down the Lakes but 100,000 tons of ore, as against 7,000,000 tons to the same time in 1903, yet scarcely a blast-furnace suffered from lack of ore, substantially all, even those which had blown out through lack of orders, having ample supplies. Standard Mesabi Bessemer ore, based on 63 per cent iron when dried, not over 0.045 per cent phosphorus and not over ten per cent moisture in natural condition, has sold at $2.50, lower lake ports, as against $4.00 last season and the low point of $2.10 in 1897. Sales even at this low price will be limited this season, the great bulk of pig iron production being by furnaces having supplies on more favorable terms, through mining it themselves or through receiving it on long time contracts, and by furnaces ordinarily buying their ore, but entering the present season with unprecedentedly large stocks. Such producers are forced to sell pig iron, if at all, at prices dictated by the current value of iron ore, which points to a bare cost of production of a trifle under rather than over $10.50 at the ordinary western Pennsylvania

or valley furnace, and to a slightly lower cost at furnaces located on the lake front. The market has not declined to this point principally because there is not enough business offered to keep furnaces in operation, and it would not pay to sell a small part of a furnace's production for future delivery, when the prospects are scant of selling the balance of the production at any price. As a result furnaces have been blowing out one after another. The market is purely nominal, and it is hardly safe to go further in naming definite quotations than to say that Bessemer or No. 2 foundry has been easily purchasable at $12.00, f.o.b. valley or western Pennsylvania furnace, with forge at 50 cents less, and these prices being susceptible of some shading on firm offers. In the south pig iron has declined at least as far as the basis of $9.00, Birmingham, for No. 2.

Steel. — The market is purely nominal, the regular prices of the billet association being shaded $1.00 to $2.00 a ton on small orders which are occasionally placed. A total collapse of the association, with its attempt at artificial control of the market, is imminent but may possibly be averted by some action which may be taken at the meeting to be held early in July.

Finished Material. — Butt weld sizes of merchant pipe were reduced one point, or about $2.00 per short ton, June 1, but shading on any desirable business carries the actual market price a point or a point and a half below the new basis. The official price of sheets has been reduced $2.00 a ton to 2.20 cents for black and 3.20 cents for galvanized, No. 28 gauge. This official price is subject to nearly as great concessions, on desirable business, as was the former price, and carloads are easily obtained at 2.15 cents for black and 3.15 cents for galvanized. Wire prices have been held quite well at the official schedule for Pennsylvania and eastern Ohio points, but there has been sharp competition for deliveries at more distant points, the shading amounting to as much as $3.00 a ton on the Pacific coast. An early reduction in the official price by $2.00 a ton is confidently expected by the trade. Light and narrow plates have been weak, but it is claimed the regular association mills are holding strictly to prices on wide and heavy plates, the manufacture of which the large mills in the association control. Rails remain at $28, but there is no question that this year will be the smallest in tonnage for many years. Rails 30 to 45 pounds per yard have sold at from $20 to $22, not being under pool control.

RECENT PUBLICATIONS

The Journal of the Iron and Steel Institute. No. II, 1903, 819 pages, numerous illustrations. Edited by Bennett H. Brough. E. & F. N. Spon, London. — This volume includes the minutes of the proceedings of the September (1903) meeting of the Institute, held in Barrow-in-Furness, and the usual valuable "Notes on the Progress of the Home and Foreign Iron and Steel Industries." The following papers were read and discussed at the meeting:

Presidential address, Andrew Carnegie.

"Alloys of Iron and Tungsten," by R. A. Hadfield, with 39 pages of discussion by F. W. Harbord, J. E. Stead, Thomas Andrews, W. F. Barrett, Joseph Bedford, H. C. H. Carpenter, G. Charpy, L. Cubillo, P. H. Dudley, L. Dumas, L. Guillet, H. H. Guy, E. Heyn, R. S. Hutton, A. Ledebur, F. Osmond, Steinhart and Vogel, Professor Turner and B. Winder.

"The Restoration of Dangerously Crystalline Steel by Heat Treatment," by J. E. Stead.

"Sorbitic Steel Rails," by J. E. Stead, with 30 pages of discussion by A. W. Richards, Tom Westgarthy, C. H. Ridsdale, E. F. Lange, R. Price Williams, L. Napier Ledingham, Professor Turner, R. A. Hadfield, J. E. Stead, Thomas Andrews, J. O. Arnold, A. Campion, D. Flather, Cosmo Johns, E. Osmond, R. G. Scott and W. R. Webster.

"The Probability of Iron Ore Lying Below the Sands of the Dadon Estuary," by James Leslie Shaw; discussed by B. J. Indus and Walter Crooke.

"Coal as Fuel in Barrow-in-Furness," by W. E. Pettegrew.

"Diseases of Steel," by C. H. Ridsdale; discussed by J. E. Stead, Professor Turner, Andrew Carnegie and W. R. Webster.

"Note on the Manufacture of Weldless Steel Pipes and Shells," by Heinrich Ernhardt; discussed by R. M. Daelen.

"The Regulation of the Combustion and Distribution of

the Temperature in Coke-Oven Practice," by D. A. Louis; discussed by W. Hawdon.

"The Influence of Silicon on Iron," by Thomas Baker; discussed by Professor Turner, A. Campion, R. A. Hadfield, J. W. Spencer, J. E. Stead and L. Guillet.

"The Diffusion of Sulphide Through Steel," by E. D. Campbell; discussed by J. O. Arnold, A. M'William and J. E. Stead.

"Notes on the Heat Treatment of Steel Rails, High in Manganese," by J. S. Lloyd; discussed by J. E. Stead.

"The Heat Treatment of Steel," by William Campbell.

"The Burning and Overheating of Steel," by H. Stansfield; discussed by J. E. Stead.

Proceedings of the American Society for Testing Materials, Vol. III, edited by the Secretary and published by the Society. 490 6 × 9-in. pages. — This volume contains the proceedings of the sixth annual meeting of the Society held at Delaware Water Gap, Pa., July 1, 2, and 3, 1903. The size of the book and a perusal of its contents testify to the rapid growth of the American Society of Testing Materials and to its useful and excellent work.

Annual Report of the Smithsonian Institution. Washington, Government Printing Office, 1903; 687 6 × 9-in. pages, profusely illustrated. — This extremely interesting annual publication contains, beside the report of the secretary, the usual number of reprints from scientific papers covering a wide range of subjects. The illustrations are excellent and printed on heavy plate paper.

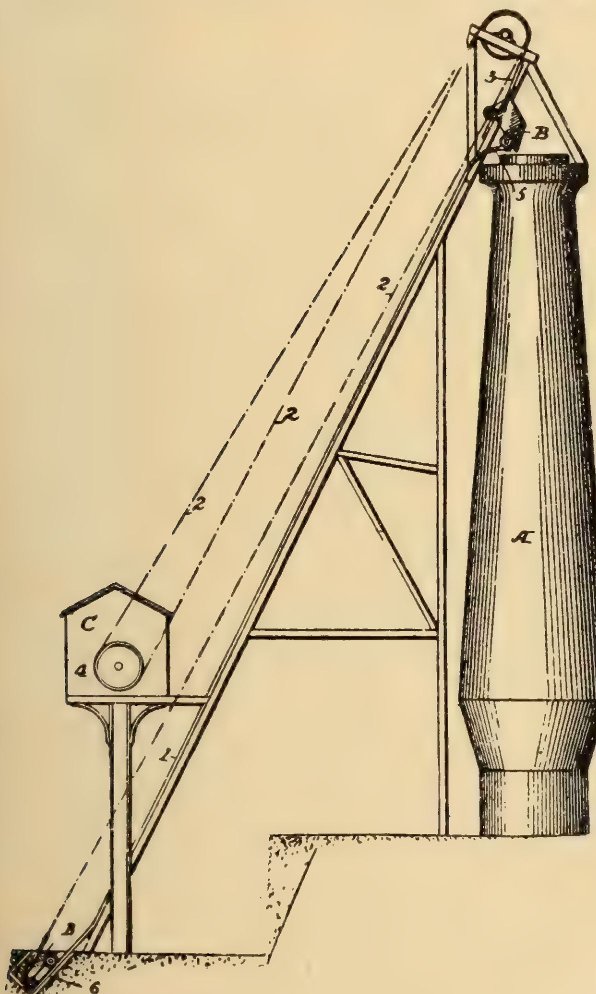
Introduction to Metallurgical Chemistry, by J. H. Stansbie. 200 4½ × 7-in. pages, 46 illustrations. John Wright & Co., Bristol, England. 1903. Price, 4/6 net. — In his preface the author states that his little book is intended for the use of technical students who are desirous of making a study of the metals employed for industrial purposes and that it must be regarded strictly as a preparatory course, before the study of metallurgy proper. At the end of each chapter there is a summary and a set of questions and the book also includes the description of 120 carefully selected experiments.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

756,821. Hoisting Equipment. — G. W. Bollman, Pittsburg, Pa. Combination with double tracks of lifting apparatus and with cars traveling thereon, of cable connected to each car, means for driving cable alternately in opposite directions and upper and lower inclined track sections, of lower grade diverging from main tracks, lower inclined sections diverging at lower grade in opposite direction, cars running on tracks and each connected near rear with one end of lifting cable, and engine-driving lifting cable.*



756,946. Feeding Mechanism for Billet-Heating Furnaces. — Victor E. Edwards, Worcester, Mass., assignor to the Morgan Construction Company, Worcester, Mass. In a furnace for heating billets, the combination with the heating-chamber and a track for billets extending lengthwise through said heating-chamber, of a pushing mechanism for pushing the billets along said track and a pair of feed-rolls one placed above the other and inserted in an opening in the walls of the furnace with their axes within the plane of the inner surfaces of the end and side walls of the furnace, said rolls being arranged to feed a billet transversely to said track and in front of said pushing mechanism.†

* "Mining and Scientific Press," April 30, 1904.

† "The Engineering and Mining Journal," April 21, 1904.

757,211. Elevating and Lowering Device for Blast-Furnace Bells. — William I. Mann, Pittsburg, Pa. A device for elevating and lowering blast-furnace bells comprising a flexible member adapted to be connected directly to the bell, a rocking drum, an air-cylinder, a piston operating in said cylinder, and connected directly to said flexible member, a counter-weight connected to the said piston, a flexible connection between said piston and said drum, and operating means for said drum.*

757,276. Process of Converting Crude Iron into Malleable Iron or Steel. — John J. Deemer, Chester, Pa. In the conversion of molten crude or cast iron into malleable iron or steel, subjecting the bath of molten metal to the action of oxidizing-blasts directed over the surface area of the bath by means of an annular series of jets extending upwardly and obliquely and converging at a common point centrally above the bath-surface.*

757,339. Metal-Tongs. — Jesse R. Oakley, Braddock, Pa. Tongs comprising an upper support, a lower support having swinging jaws with projecting lever-arms, and flexible connections on the upper support arranged to engage either the lever-arms or the jaws.*

757,386. Method of Reducing Metal Bars into Sheets. — Thomas V. Allis, Bridgeport, Conn. A method of reducing metal bars into sheets in pile in a heated state, which consists in first reducing hot bars to plates by passing the bars between roughing-rolls; second, collecting while hot the plates thus produced one upon another in pile within a heating-furnace and finally transferring and subjecting such pile so heated and while hot to the action of rolls to reduce the plates therein to sheets.*

757,453. Machine for Separating Metal Sheets. — George Grove, Cumberland, Md. The combination of a series of magnets spaced apart with an opposite series also spaced apart, the spaces of one series being opposite the magnets of the other series and means for feeding a pack of metal sheets between the series.†

757,454. Process of Separating Metal Sheets. — George Grove, Cumberland, Md. A process herein described for separating metal sheets from packs which consists in causing the pack to pass between magnets arranged to act in opposite directions on opposite sides of the pack.†

757,582. Process of Welding Steel Plates, Etc., to Sheets of Aluminium and Aluminium-Plated Other Metals. — Heinrich Wachwitz, Hersbruck, near Nuremberg, Germany, assignor, by direct and mesne assignments, to the Wachwitz Patents Syndicate, Limited, London, England. A process for welding plates or bodies of steel or other metals which are liable to slow oxidation when being heated, to sheets, of aluminium or other metals plated with aluminium, consisting in cleaning the surfaces of the aluminium or aluminium coating and of the steel plate, or other metal plate which surfaces are subsequently to be placed in juxtaposition, placing the metals to be welded upon the steel plate or other metal plate, heating them to a moderate temperature and uniting them by a suitable pressure by means of rolls or other appliances sufficiently

* "The Engineering and Mining Journal," April 21, 1904. † *Ibid.*, April 28, 1904.

to prevent oxidation of the junction when being further heated, then further heating the compound plate close to the melting-point of the metal plated upon the steel or other plate, and welding the same by rolling or other pressure in this state.*

757,604. Apparatus for Cutting Metal Bars. — Victor E. Edwards, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass. The combination with the cutting mechanism, comprising a reciprocating ram provided with a cutting-blade, of a pivoted platform for supporting the piece severed from the bar, an intermediate pivoted lever connected with said reciprocating ram, and also connected with said bar-supporting platform whereby said platform is rocked simultaneously with the operation of cutting.*

757,803. Process of Treating and Manufacturing Steel. — Walter B. Burrow, Norfolk, Va. The introduction of dephosphorizing material in a pulverulent form, in the manufacture of steel, by means of the air-blast under pressure in different thickness or depths of the molten metal and by drawing in the dephosphorizing material at a certain stage of the process by means of a vacuum, and the expulsion of the gases from the vessel on the introduction of the purifying material into the converter.*

758,003. Adjusting Mechanism for Sheet-Mills. — Sumner B. Ely, Allegheny, and Harry H. Anderson and William W. Slick, Pittsburg, Pa., assignors to American Sheet Steel Company, New York, N. Y. In roll-adjusting mechanism, the combination with the adjusting-screws of an operating-lever, connections between said lever and both screws, whereby the latter may be rotated, and means operated from said lever for disengaging the rotating means from both screws.*

758,387. Compound Metal Ingot. — Richard Rowley, Clearfield, Pa. In combination a muck-bar having opposed flanges on its opposite edges with a muck-bar having its sides shaped to fit against the inner faces of the flanges on the other bar, said second bar being of a size conforming to and filling the space between the flanges on the first bar and forming when laid thereon a solid pile.†

758,498. Charging Apparatus for Blast-Furnaces. — K. Backlund and B. F. Burman, Baltimore, Md. In charging machine for furnaces, combination with movable truck; stock chamber thereon having outlet in bottom thereof and inlet, distributing bell within outlet and adapted to support stock chamber, automatically operated closure for inlet, and means for imparting vertical movement to bell and chamber.‡

758,529. Manufacture of Flanged Metal Bars or Beams and Structural Work. — Henry Grey, New York, N. Y., assignor to American Universal Mill Company, New York, N. Y. A process of making shapes of the class described, which consists in taking a blank the thickness of the web of which bears substantially the same relation to the mean thickness of each of the flanges thereof as these respective dimen-

* "The Engineering and Mining Journal," April 28, 1904.

† *Ibid.*, May 5, 1904.

‡ "Mining and Scientific Press," May 7, 1904.

sions bear to each other in the finished shape, subjecting said blank to a series of rolling operations and maintaining during said operations the aforesaid relation between the web and flanges.*

758,655. MAGNETIC ORE-SEPARATOR. — William L. Imlay, Philadelphia, Pa., assignor to Adolph Segal, Philadelphia, Pa. A magnetic ore-separating apparatus consisting of a rotating drum containing a magnet, said magnet having a hub carrying two sets of segments forming a drum and wire wound on said drum, certain of the segments being of magnetic material and forming the pole-pieces of the magnet and the others being of non-magnetic material and serving to retain the wire in position.†

758,660. APPARATUS FOR MAKING CASTINGS. — William T. James, Chicago, Ill. In casting apparatus the combination with a pair of movable circular racks and means for moving the same, of a series of reversible molds mounted upon said racks, resting upon pinions on said racks, and means for inverting said molds by rolling them on said pinions.†

758,812. SLAG-CAR. — Benjamin H. Bennetts and Llewellyn J. W. Jones, Tacoma, Wash. In a slag-car, the combination with a truck, of a slag-pot mounted on said truck and adapted to dump the slag in a solid mass in any direction from said truck, a hook pivoted to said slag-pot and adapted to engage said truck whereby said pot is prevented from turning on said truck and from tipping thereon, and a handle engaging the rear end of said slag-pot and bent so that when said pot is down said car may be pushed by said handle and when it is tipped up said handle may be within reach whereby the dumping of the slag may be controlled.†

758,853. METHOD OF CONVERTING IRON-SAND INTO BRIQUETTES OR LUMPS. — Thomas Rouse, Stamford Hill, England, assignor of one-half to Herrmann Cohn, London, England. A process of agglomerating by means of solution of water-glass and hardening into lumps or hard blocks, iron-sand, powdered iron ore or blue-billy or the like, or mixtures thereof, by means of a mixture of hot air and steam at atmospheric pressure in a ventilated chamber, in which condensation of the steam into a deposit of water of condensation is prevented by regulating the supply of hot air and steam and the ventilation.†

759,449. LEAK DETECTOR FOR TUYÈRE, COOLING BOXES, ETC. — Andrew C. Kloman, Pittsburg, Pa. A cooling device having a passage therein for a cooling fluid and an inlet and an outlet therefor, a rotary device in said passage constructed to rotate when the inflow is greater than the outflow, and means whereby the rotation of the rotary device may be indicated.*

759,644. TURNING APPARATUS FOR ROLL-TIRES. — Thomas L. Sturtevant, Quincy, Mass., and Thomas J. Sturtevant, Wellesley, Mass., assignors to Sturtevant Mill Company, Portland, Me., and Boston, Mass. In a turning or machining attachment for crushing, rolls, the combination with a turning-tool device and a driving-shaft of a swinging arm or frame, a counter-shaft carried by said swinging arm or frame, driving connections between said power-shaft and said counter-shaft, and means on said counter-shaft for driving the crushing roll to be turned or machined.*

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* "The Engineering and Mining Journal," May 5, 1904. † *Ibid.*, May 12, 1904.

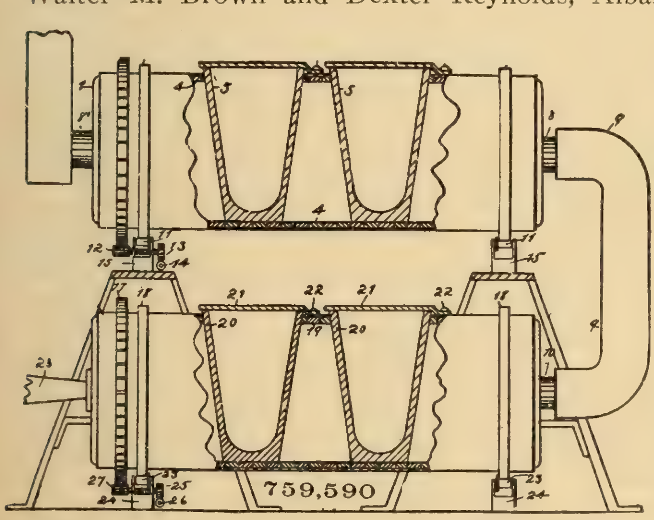
759,171. HOT-BLAST APPARATUS FOR METALLURGICAL FURNACES. — Ambrose P. Gaines, Bessemer, Ala. In a hot-blast apparatus for metallurgical furnaces, the combination with a furnace, a regenerative stove or chamber, means for supplying a blast of air thereto, and a closable connection between said stove and furnace through which the hot-blast passes to the furnace, of a plurality of combustion-chambers separate from the stove, a closable connection between each combustion-chamber and stove through which hot gases and products of combustion pass from the chamber to the stove, and means for supplying gases for combustion in said combustion-chambers.*

759,326. ROLLING-MILL. — James D. Swindell, Pittsburg, Pa., assignor to American Furnace & Machine Co., Pittsburg, Pa. The combination of two presser-rolls, a flexible guide device disposed at one side of and normally bearing against one of said rolls to direct material over the same, and adjustable yielding means connected with the free end of said flexible device for holding the same against the rolls.*

759,526. WELDING-FLUX. — William W. Hout, Cortland, N. Y. A welding-flux or compound consisting of calcined borax, iron or steel filings, drillings or cuttings, furnace dross, slag or cinder, and calcined marble-dust.*

759,557. CONVEYOR OR CATCHER FOR ROLLING-MILLS. — Charles Scholtz, Sharon, Pa., assignor to the Sharon Steel Hoop Company, Sharon, Pa. A conveyor or catcher for rolling-mills and the like, comprising a plurality of rollers, and an independent driving-motor connected directly to the axle of each roller.*

759,590. PROCESS OF PRODUCING IRON OR STEEL DIRECT FROM ORE. — Walter M. Brown and Dexter Reynolds, Albany, N. Y. A process of producing iron and steel direct from the ore consisting of mixing granulated oxide-of-iron ore with granulated carbonaceous material in quantity and quality sufficient to deoxidize the ore and carbonize the iron to the grade of iron or steel desired; heating the mixture by the heat only of waste products of combustion and stirring and intermixing the mixture while being thus heated, and protecting it from contact with said products of combustion, except the heat, and from contact with the atmosphere until the iron is deoxidized and suitably carbonized, after deoxidation and carbonization has taken place, introducing into the mixture flux sufficient



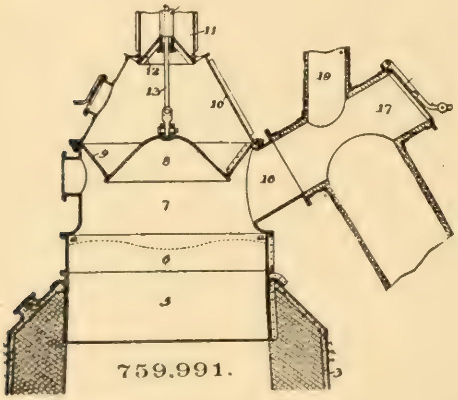
* "The Engineering and Mining Journal."

in quantity and quality to remove impurities; heating the mixture by means of the heat from an initial source of heat and at the same time protecting the mixture from contact with the rest of the products of combustion and from the atmosphere, until melting or fusion of the iron results, the waste products used being from the initial source of heat.*

759,750. APPARATUS FOR THE INTRODUCTION OF PULVERULENT SUBSTANCES INTO CONVERTERS, ETC. — Gustav Rosenthal, Letmathe, Germany. In a device for introducing pulverulent substances into converters, blast-furnaces, the combination with the blast-conduit, of two pipes, abutting into the same, more or less vertically and in opposite directions opposed to and in the direction of the blast-current, the receptacle arranged above the pipe containing the pulverulent substances, communicating with each other and thereby adapted to, on the blasting-current passing through the blasting-conduit, produce a pressure in one of the pipes and a corresponding vacuum in the other, under the influence of which a quantity of the pulverulent substance, proportional to the velocity of the blasting-current, is sucked off from the receptacle and carried by the blasting-gases to the metallurgic apparatus.*

759,984. ROLLING-MILL. — Jerome R. George, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass. A rolling-mill, consisting of a pair of two-high rolls having a series of grooves or passes for the continuous reduction of an ingot, a straight conveyor by which an ingot can be presented to a portion of the passes in opposite directions, and one or more curved repeaters connecting the remaining passes in consecutive order, with one of the passes of the rolls arranged to receive an ingot from said conveyor and deliver it to one of said curved repeaters.†

759,991. BLAST-FURNACE. — George K. Hamfeldt, Munhall, Pa. A blast-furnace having an annular metal shell with its lower portion within the upper part of the masonry stack, said shell being extended above said stack and having its upper portion where the dropping charge strikes it of smaller diameter than the internal diameter of the top of the stack proper.†



759.991.

760,189. PLANT FOR FEEDING METALLURGICAL FURNACES. — Ambrose P. Gaines, Bessemer, and Edwin R. Cox, Jr., Birmingham, Ala. In a plant for feeding materials to furnaces, the combination with a furnace, of a vertical hoist, a bridge connecting the furnace with said hoist, a cage operating in said hoist, a car carried by said cage and adapted to traverse the bridge to the furnace for discharging materials therein when the cage is at its upper landing, one or more bins provided with chutes arranged to deliver material into the car while held stationary on the

* "The Engineering and Mining Journal." † *Ibid.*, May 26, 1904.

cage at said landing, and means for weighing the loaded car at said lower landing before hoisting.*

760,263. Regenerative Gas-Furnace. — Frederick Siemens, Dresden, Germany. In a regenerative gas-furnace, means for increasing the temperature of the producer-gas, said means consisting of a gas-flue and an air-flue for conducting highly-heated air, the wall of one flue forming the dividing-walls between the flues, said flues communicating with each other at intervals throughout their length by ports in the dividing-wall through which a portion of the contents of one flue may issue into the other flue and combining with a portion of the contents thereof produce flames by which the said contents are heated.*

760,582. Tongs for Furnace-Charging Cranes. — Clarence L. Taylor, Alliance, Ohio, assignor to the Morgan Engineering Company, Alliance, Ohio. The combination with tongs-carrying frame, of tongs each having a bit at its free end to engage the slab or ingot and an inwardly-projecting shoulder or abutment in rear of its bit, and means for actuating the tongs.†

760,523. Metal-Casting Machine. — Ernest Crossley, Canton, Ohio, assignor to the Aultman Company, Canton, Ohio. In a pig-casting mechanism, the combination of the mold-carrier, a series of molds rotatively mounted on the carrier on axes substantially radial to the axis of rotation of the carrier, the two-part holding device to prevent rotation of the mold on its axis, one part consisting of a stationary bar held independently of the molds and mold-carrier, and the other part carried by the mold and engaging with the stationary part.*

760,600. Apparatus for Welding Iron and Steel. — Abram C. Allen, Dayton, Ohio, assignor to Eugene Kennedy, Montgomery County, Ohio. A welding-furnace having a heating-hearth for heating materials to be welded, and an anvil within said furnace adjacent to the heating-hearth, whereby the materials to be welded may be heated upon said hearth in said furnace and welded upon the anvil without removing any of the parts from the furnace.*

760,633. Method of Avoiding Loss of Heat in Furnaces. — Adalbert Kurzwernhart, Zuckmantel, near Teplitz, Austria-Hungary. A method of avoiding loss of gas in Siemens regenerative furnaces wherein, before the reversing operation, the gas contained in the regenerative chamber and in the passages connected therewith is forced into the furnace by air which, after the gas has been cut off in a known manner, is introduced through a lateral opening.*

760,825. Annealing Apparatus. — Edward A. Uehling, Passaic, N. J. The combination of a car adapted to convey annealed material, said car being provided with a fireproof floor, an open metal box erected upon said floor, means for dividing a part of the interior of said box into rectangular portions, means for filling said portions with molten material to be annealed, means for substantially covering said rectangular portions with an envelope of the said molten material, and means for discharging the contents of said car.†

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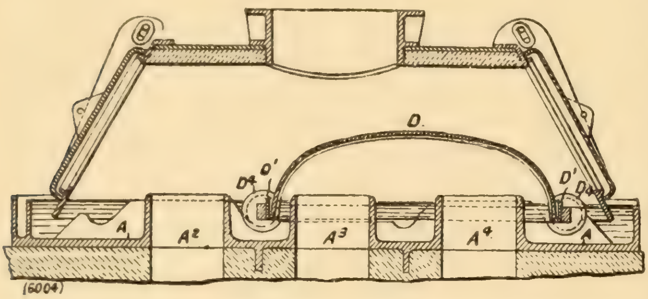
* "The Engineering and Mining Journal," May 26, 1904. † *Ibid.*, June 2, 1904.

GREAT BRITAIN

6,004. Regenerative Furnaces. — William Beardmore and Co., Ltd., and C. G. Atha, Glasgow. (2 Figs.) March 16, 1903. This invention relates to what are known as water-sealed reversing valves for regenerative furnaces, and has for object to improve and simplify the construction and operation of the carrying and operating mechanism of such valves. The valve for controlling the passage of the gases is an arch-shaped piece of metal D forming a hood of a size sufficient to cover two of the three ports A^2, A^3, A^4 at one time, and according to this invention it is carried on a frame D^1, having axles on which are wheels D^4 running on rails along each side of the bedplate A. These rails are of such a height that when the valve hood is covering two ports, the lower edge dips into the water seal and prevents the possibility of leakage of the gas. The rails are also made with raised parts, so that when it is desired to reverse the direction of flow of the gases, and the valve hood is shifted, the wheels will encounter and ride up one side of the raised parts on the rails. This will lift the valve hood out of the water seal, and above the level of the ports. The raised parts on the rails are of such a length that the valve hood will be kept in this raised position until it has almost reached its second position, when the wheels will pass down the other side of the raised parts on the rails, and the valve hood will be lowered again into the second sealing position. (*Accepted February* 17, 1904.)*



8,298. Steel. — T. J. Tresidder, Sheffield. April 9, 1903. This invention has for its object to provide steel of such a character that, while readily receptive of a vibrous structure under suitable treatment, it can retain that fibrous structure under conditions that would ordinarily produce a crystalline structure, such, in particular, as the sudden chilling from a very high temperature necessary in the process of face-hardening after supercarburization. The steel, according to this invention, has the following composition, namely: iron, carbon, manganese, nickel, and tungsten, in or about the following proportions in each ten thousand parts by weight of the steel mixture: carbon, from 28 to 32 parts by weight; manganese, from 25 to 30 parts by weight; nickel, from 225 to 250 parts by weight; tungsten, from 28 to 32 parts by weight; the remainder being iron with such impurities as usually cannot be avoided in practice, such as silicon, sulphur, phosphorus, cobalt, arsenic, copper, and the like. In other words, the average composition of this steel is as follows: of carbon,

* "Engineering" (London), April 8, 1904.

manganese, and tungsten, each about three-tenths of one per cent, and of nickel 2½ per cent, the remainder being iron, as aforesaid. Silicon may be present up to 10 or 15 parts by weight without detriment, while the others, if their presence cannot be avoided, should be present in as small a quantity as is possible. (*Accepted February* 10, 1904.)*

5,866. Regenerative Gas Furnaces. — F. Siemens, London. (12 Figs.) March 13, 1903. This invention relates to improvements whereby the most modern type of Siemens regenerative gas furnace is made suitable for burning producer gas or blast-furnace gas, which has been subjected to a treatment in which it is completely deprived of its sensible heat, without reverting to the use of expensive gas regenerators. The cool gas is conducted to the furnace through a flue or flues C, preferably of considerable length and size, to properly expand or reduce the velocity of the gas, and so shaped towards the furnace chamber E that they expose a larger surface to heat directly radiated therefrom; for example, the flues may be coned outwardly towards the furnace as shown. The gas flues may get hot by radiated heat from the furnace chamber, become regenerators, and serve alternately to heat the combustible gas. The part of the regenerative gas flues exposed to the heat of the furnace chamber may be provided with any known device for better absorbing the radiated heat, such as chequer work B. Gas regenerators, according to this invention, are thus not heated at all by passing the gaseous combustion products of the furnace through them, nor have they any direct connection with the chimney, as in furnaces at present constructed for using cold producer gas. (*Accepted February* 17, 1904.)*

Fig. 1.

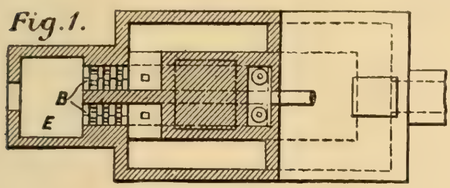
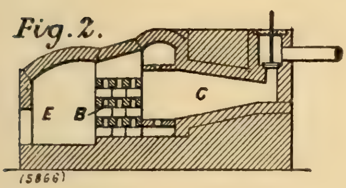


Fig. 2.



9,689 of 1903. Crucible Furnace. — J. Baxeres de Alzugaray, London. Improved form of crucible furnace, the chambers being arranged to give a specially high degree of heat.†

1,842 of 1904. Hardening Steel. — E. Engels, Düsseldorf, Germany. Improvements in inventor's hardening process for steel, by surface treatment with carbides and subsequent rolling or pressing.†

11,002 of 1903. Steel Melting. — A. Reynolds, London. In melting steel, providing a slag to float on it, and heating the slag by means of electric arcs.‡

3,235 of 1904. Iron Ore Briquettes. — H. Schulte-Steinberg, Bochum, Germany. Use of blast-furnace slag for binding iron ores into briquettes for smelting.||

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* "Engineering" (London), April 8, 1904.

† "Engineering and Mining Journal," April 21, 1904.

‡ *Ibid.*, May 12, 1904. || *Ibid.*, May 5, 1904.

4,894. Puddling Furnaces. — J. Jones, Tipton, Staffs. (2 Figs.) March 3, 1903. This invention relates to puddling and similar melting and reheating furnaces. In building up a furnace according to this invention, the exterior part of the furnace is provided with double walls *a, c,* providing between them air-passages *e* proceeding from the chimney end *f* of the furnace to the front end of the fire-chamber. The air that enters these passages is cold, and in its travel to the front end of the fire-chamber becomes heated by radiation from the confining walls *c* of the fire-chamber *g* and metal chamber *i*. From the passage or space at the front of the fire-chamber the air proceeds over the fire to the fire-chamber *g*, and is used for the combustion of the smoke and gases, preferably passing into the fire-chamber by way of perforations *h*. The metal or melting chamber is provided as ordinarily. It will be seen that the air-passages are so built between the walls *a* and *c* that the air cannot reach the upper part of the metal chamber other than by passing over the top of the fire, where it is utilized for combustion. Instead of the perforations *h*, a single large opening may be provided; *j, k, l, m* are the usual openings for feeding the fire with fuel and placing the metal or the like within the heating or melting chamber. (*Accepted February* 24, 1904.)*

Fig. 1.

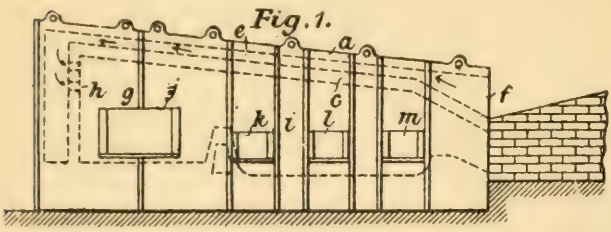
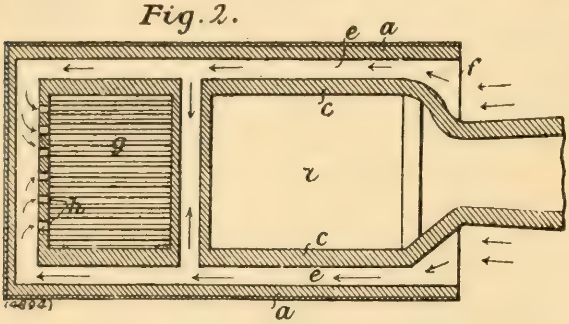


Fig. 2.



912 of 1904. Making Steel Castings. — J. Matzek, Mülheim, Germany. Improved method of applying electric current for preventing the formation of cavities inside and irregularities on the surface of steel castings.†

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* "Engineering" (London), April 22, 1904.

† "The Engineering and Mining Journal," May 5, 1904.

SEVENTH ANNUAL MEETING OF THE AMERICAN SOCIETY FOR TESTING MATERIALS

ATLANTIC CITY, JUNE 16, 17 AND 18, 1904

The Iron and Steel Magazine

". . . . . . Je veux au mond publier
d'une plume de fer sur un papier d'acier."

Vol. VIII August, 1904 No. 2

THE AMERICAN SOCIETY FOR TESTING MATERIALS

THE seventh annual meeting of the American Society for Testing Materials was held at Atlantic City, New Jersey, June 16, 17 and 18. Some 150 members were in attendance and the meeting was in every respect a highly successful one. President Dudley occupied the chair at every session, which he directed with his usual admirable tact and urbanity. The growth of the society, the excellent program prepared for this meeting and the manner in which it was carried out stand as so many evidences of the wisdom of the society in selecting for their secretary Professor Edgar Marburg.

The secretary reported an even membership of 500, whereas a year ago it stood at 349, a growth which testifies to the excellent work being done by the society and to the wide interest taken in its aims by manufacturers, consumers and engineers.

The principal officers of the society were reëlected for the coming year as follows: President, Dr. C. B. Dudley; Vice-President, Mr. R. W. Lesley; Secretary-Treasurer, Professor Edgar Marburg. Mr. James Christie was elected member of the Executive Committee. Reports were presented from the following committees:

Committee E — "On Preservative Coatings for Iron and Steel"; S. S. Voorhees, Chairman.

Committee B — "On Standard Specifications for Cast Iron and Finished Castings"; Walter Wood, Chairman.

Committee C — "On Standard Specifications for Cement"; G. F. Swain, Chairman.

Committee A — "On Standard Specifications for Iron and Steel"; W. R. Webster, Chairman.

Committee B — "On the Magnetic Testing of Iron and Steel"; J. Walter Esterline, Chairman.

Committee H — "On Standard Tests for Road Materials"; L. W. Page, Chairman.

Besides the President's excellent annual address on the "Influence of Specifications on Commercial Products," the following papers were presented, some of them giving rise to prolonged and earnest discussions:

"Results of an Investigation Concerning Causes of Durability of Paints for Structural Work." Robert Job.

"Alloy Steels: Self-Hardening and High-Speed." William Metcalf.

"Some Statistics of the Cement Industry in America." R. W. Lesley.

"Cast Iron: Strength, Composition, Specifications." William J. Keep.

"Pig Iron Feasts and Famines: Their Causes and How to Regulate Them." George H. Hull.

"Report on the Specifications for Iron and Steel Structures, American Railway Engineering and Maintenance of Way Association, as Amended and Adopted in March, 1904." J. P. Snow.

"Comparison of the Specifications for Axles and Forgings, Proposed by Committees of the American Railway Master Mechanics Association, and the American Society of Mechanical Engineers, with the Standard Specifications Adopted by the American Society for Testing Material." H. V. Wille.

"Specifications for Air-Brake Hose." Max H. Wickhorst.

"A Brief Review of the Status of Testing in the United States." Gaetano Lanza.

"Structure of Alloys." William Campbell.

"The Effects of Preservative Treatment on the Strength of Timber." F. A. Kummer.

"The Early History of 60,000-Pound Structural Steel." Samuel Tobias Wagner.

"The Commercial Testing of Sheet Steel for Electrical Purposes." C. E. Skinner.

"Permeability of Cast Steel." H. E. Diller.

"Proposed Tests for Controlling the Heat Treatment of Structural Steel." J. P. Snow.

"Tests for Detecting Brittle Steel." William R. Webster.

"Nomenclature of Iron and Steel." Albert Sauveur.

"Tensile Impact-Tests of Steel." W. K. Hatt.

"The Desirability of a Uniform Commercial Speed for Testing." Paul Kreuzpointner.

"Staybolt Iron and Machine for Making Vibratory Tests." H. V. Wille.

"A New Chuck for Holding Short Test Pieces." T. D. Lynch.

"Bending Moments in Rails." P. H. Dudley.

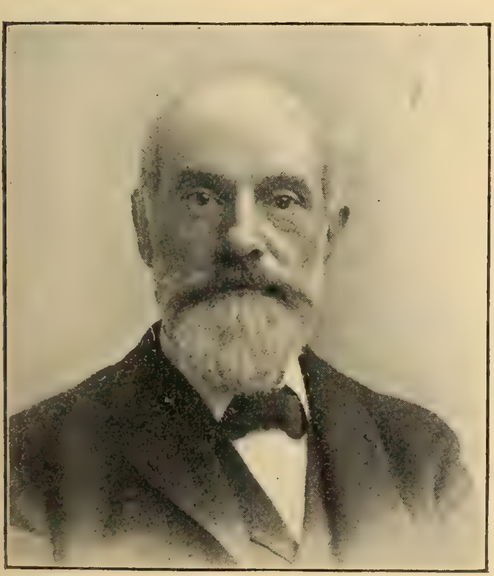
The reports from Committees A and B on steel and cast iron were presented practically in their present form at the last meeting of the American Institute of Mining and were published in full in the April issue of *The Iron and Steel Magazine.* The report of Committee E "On Preservative Coatings for Iron and Steel" will be found abstracted in this issue, while the other report dealing with iron and steel, namely that of Committee B on magnetic testing, will be published in an early issue.

The papers presented at this meeting which are of special interest to our readers will be found reproduced in full in the present number of *The Iron and Steel Magazine.*

ALLOY STEELS*

By WM. METCALF

THE term alloy steels is used chiefly to distinguish steels containing influencing quantities of metals other than iron



from the ordinary steel of commerce known as carbon steel, in which iron and carbon are the influencing elements for use, other elements being considered more as impurities than as useful ingredients. There are three kinds of carbon steel of universal use: crucible, Bessemer and open hearth. Their discussion does not belong properly to our subject; but it may be observed that they contain small quantities of phosphorus, sulphur, silicon and manganese, as well as oxygen, nitrogen and hydrogen. Copper and arsenic are present sometimes but not so

* Read at the Atlantic City meeting (June, 1904) of the American Society for Testing Materials.

generally or in such quantity as to require the careful analyses that are necessary for other ingredients.

Certain small percentages of silicon, and of manganese are often regarded as useful for special purposes but not in such quantities as to justify their giving any specific name to the steel. From time to time we have had put upon the market silicon steel, phosphorus steel, chrome steel, aluminium steel, none of which have won any permanent place in commerce. Of permanent alloy steels we have nickel steel, manganese steel, self-hardening or air-hardening steel, and the latest, the new variety called high speed steel.

Nickel Steel. — Nickel steel containing comparatively small percentages of nickel is used chiefly for structural purposes, giving increased strength and toughness. It has been applied mostly to armor plates and gun parts, and lately it is being tested largely in rails to determine whether the increase in durability in difficult places will justify the greater cost over ordinary Bessemer or open-hearth rails.

Manganese Steel. — Hadfield's manganese steel is unique — hard, tough, non-magnetic, non-hardening by quenching, non-annealable by any known method, practically unmachinable. It stands by itself; there is nothing to compare it to, nor to test it by. It is finding large use for a number of special purposes.

Self-Hardening, or Air-Hardening Steel. — This steel derives its name from the fact that when it is heated to an orange color and allowed to cool slowly in the air it becomes exceedingly hard. Some years ago it was known generally as Mushet steel from the fact that its first development was due to the distinguished metallurgist whose name it bore. The usual composition of this steel is about two to three per cent manganese, four to six per cent tungsten, and carbon high.

The distinctive, persistent hardness of manganese steel indicates that it is manganese that gives this steel its so-called self-hardening property. This was confirmed many years ago by Langley, who found that steel high on carbon, containing about four per cent tungsten and minute quantities of manganese had no self-hardening property, and that the same steel remelted so as to contain three per cent Mm became an excellent self-hardening steel. Langley next showed by his beautiful emery wheel test, that tungsten is the element that acts as a mordant to hold the

carbon in solution at a high temperature, giving this steel its most valuable property, that of remaining hard at a comparatively high temperature, so that a tool made of it could be used for cutting metals at a high speed; the tool continuing to do its work at a temperature caused by the enormous friction of the high speed, that would soften completely and render useless the best carbon-steel tool that could be made. This very useful variety of steel has a large place in the markets, being used for many purposes where its peculiar properties give it great value. It is being rapidly overshadowed, however, by the latest and most surprising steel of all known as

High Speed Steel. — Air-hardening steel as a rule is not tough. That is to say, if it is made tough it will not be very hard; the edge of a tool will flow. And when it is so hard that it will not flow, then it is so brittle that it will crumble easily, and this limits its usefulness. A few years ago at the Bethlehem Steel Works some person, whether he was a blunderer or a genius history does not say, revolutionized the whole machine business. Either by design or accident he heated a tool made of air-hardening steel until it was nearly melted, and according to the traditions and teachings of the ages the tool was ruined utterly. Again, either by accident or design this ruined tool was put into service, and to the amazement of everybody it did an unheard-of amount of work. This led to further experiments and tests, and the Taylor-White process was developed. This process consisted in heating a tool excessively hot and cooling it by successive stages, producing a tool that would cut at enormous speed for metal work and take off chips that developed enough heat to blue them. The process was patented and therefore it is not necessary to go into a long explanation here, especially as it has been superseded.

The process seems to have been uncertain; that is to say, when a tool was handled just right it produced results that were wonderful, and when the manipulations were not exactly right the results were nil. The potentialities were so great that nearly all of the leading steel makers in the world attacked the problem with the result that the present high-speed steels are in no sense of the word air-hardening. Mn has been reduced from three to four per cent to 0.30 per cent to traces; tungsten has been increased to ten to 20 per cent instead of the usual four to six per cent and the carbon is generally less than one. There are

about fifty different brands on the market, and of course each one is the best. Perhaps the analysis of two of the leading brands will be interesting:

Tungsten	9.99	18.48
Chromium	2.83	2.90
Carbon	0.60	0.79
Phosphorus	0.010	not determined.
Sulphur	0.010	not determined.
Silicon	trace	not determined.
Manganese	trace	0.33

Another contains:

Molybdenum	9.65
Chromium	0.00
Carbon	0.65
Phosphorus	0.016
Silicon	0.046
Manganese	0.22

In one sense it is chaos; all traditions as to heating are completely reversed, and no one really knows what is the best. One brand is famous for its excellence in one kind of work; another in another kind; no one yet seeming to cover all of the ground. One thing is certain: the machine business is revolutionized. These tools have crowded ordinary lathes, planers, drills, etc., away beyond their capacity; machine builders are remodeling their machines to meet the new conditions, and many of the users are throwing out their old machinery for the new, or else remodeling and strengthening what they have.

There are many records published of the work done by this steel, giving speed per minute, feed, depth of cut, etc., so that it is not necessary to repeat them here. A few illustrations of what can be done may be interesting.

Performances of High-Speed Steel. — In one case a couple of steel-cast bed plates about four feet wide and nine feet long were to be planed. There was nominally a half inch to come off, but the unevenness of the casting made the cut about one inch in places. The surface was hard and gritty from the sand of the mold. Several tools were tried, each one going about half an inch and then having to be reground. Next, one tool cut about two inches without grinding. Finally, a tool was tried that had turned up a large, rusty, cast-iron pulley without grinding, and it

cut clear across the bed plates and was still in good condition for further work. It is clear that the cost per pound of that tool cut no figure.

Another party had a great many castings to thread. With dies made of the very best carbon steel, he could at moderate speed thread from 2,000 to 3,000 pieces without grinding. With dies made of high-speed steel, and with his machine running as fast as he can drive it, he threads from 20,000 to 30,000 pieces without grinding.

Another party turns many pieces of hard brasses, and found it difficult to get a tool that would cut them at all until he tried the right high-speed steel and made a tool that would cut all day without grinding, running his lathes at the highest speed he could get.

The same party bores many cast-iron cylinders, and with tools made of steel that would not cut his brass, he bores eight to ten cylinders without regrinding, and at a speed so great that the cylinders come out too hot to be handled with the naked hand. He tried in his cylinders the steel that cut his brass so well, and it would bore only two to four cylinders without grinding.

Another party drills two ⅜-inch holes seven inches deep in soft steel forgings, drilling a hole in about three minutes. The same steel will not make a good threading die for the same forgings and for this he uses another brand. Neither of these steels will make a good lathe tool for turning these forgings, and for this work he uses a third brand. All of these brands upon analysis would come within the limits of the analyses given above.

From all of this two things are clear: one is that there has been a marvelous, a revolutionary, advance in the machining of metals. The other is that steel makers have met the demand remarkably. It is also clear that we do not know yet where we are and there is much to be learned by everybody. The best methods of hardening may not have been found. It seems that for very high-speed work it is necessary to fairly melt the point of the tool and quench it in a strong air-blast and then grind to shape. This would not do for threading dies, milling cutters, etc., for the heat would destroy the tools. Such tools are finished from annealed bars. This high-speed steel can be annealed as nicely as carbon steel, differing in this respect from air-hardening steel. The finished tools are heated in a lead bath to 1,800° to 2,000°

and are quenched quickly in ordinary tempering oil which must be kept cool by a coil containing circulating cold water. They are then tempered in a bath of heavy oil heated to about 450°. The tools come out bright and clean and do their work wonderfully well.

The steel maker has the most to learn. He must find out why there is such a great difference in the work the steel will do, when there is no little difference in composition. He must find the composition or mixture that will come nearest to meeting all of the requirements. He has at command now ferro-manganese, ferro-silicon, ferro-chromium, ferro-tungsten, ferro-molybdenum, ferro-vanadium and ferro-titanium. These alloys are all expensive except the first two, costing from 60 cents to $12 a pound. Therefore the present prices of high-speed steel, which to some people seem to be of the fancy order, are really not excessive.

As far as we know at present the steel users have not succeeded in making tools that are satisfactory for finishing, and for this purpose they resort to tools of carbon steel after having done the rougher, heavier work with high-speed steel. This difficulty may be overcome by proper methods of hardening and tempering, or the steel makers may find a composition that will make a tool that is as good for finishing as for roughing. The successful production of the above-named alloys marks a great advance in metallurgy, and now that a demand has sprung up it is certain that the supply will follow, with certainty and uniformity of composition and reductions of cost.

The making and utilizing of steel containing practically only carbon and iron, with some modifications made by the use of small quantities of Mn, Si, tungsten and nickel, have occupied the best minds in the manufacturing and engineering world for many years. The last half of the nineteenth century saw most wonderful developments produced by the inventions of Bessemer and Siemens, aided by the skill and energy of the brightest engineering minds. At the close of the century it was customary to "point with pride" and to assume that so much had been done and so much was known, that there was no room for more revolutionary changes, and that the coming generation had only to tag along, utilizing these great advances with ease and comfort to themselves, and with blessings upon their predecessors.

Now, in the first five years of the twentieth century, we older men find ourselves standing on our heads once more. A revolution has come already; and we can look forward to a splendid opening for the exercise of the best energy and thought of the succeeding generation.

We enjoyed the struggle and the gains of our time and we can rejoice with the younger men in the prospect of the great triumphs that are to come for them. Clearly there is still plenty to do, and plenty to learn, and in the doing of them there will be great pleasure.

THE COMMERCIAL TESTING OF SHEET STEEL FOR ELECTRICAL PURPOSES*

By C. E. SKINNER
Pittsburgh

AT the present time the rate of consumption of sheet steel in the manufacture of electrical apparatus in the United States alone is probably not less than 100,000,000 pounds per year. Assuming that 20 per cent of this material is subjected to the conditions under which the so-called iron loss occurs, and that this loss is 1½ watts per pound, we find we have a total loss of 30,000 kw., or 40,000 horse-power, an amount of power approaching the output of the largest single electrical power station in existence. At the rate of $25 per horse-power per year, this represents a money value of $1,000,000. This loss manifests itself as heat in the apparatus and therefore serves no useful purpose, but forms one of the limitations to the output of the apparatus.

The losses referred to are the hysteresis and eddy-current losses, more commonly combined under the general term "iron loss." This loss occurs in all magnetic material which is subjected to alternating magnetic stresses, the amount of the loss in any given material depending upon a number of conditions which will be referred to later.

In general, the following must be taken into consideration in connection with the testing of sheet steel for electrical purposes:

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1. The losses in different sheet steels vary greatly with the chemical composition, and with the physical condition due to the heat treatment and the mechanical working which the steel has received.

2. In most sheet steel the losses may be reduced to a relatively small value by annealing.

3. Nearly all steels, when the losses are reduced to a low value by annealing, are subject in a greater or less degree to aging, or increase in loss, due to the influence of comparatively low temperatures.

4. The permeability of all steels which may be rolled commercially differs by a comparatively small amount, no matter what their condition with respect to annealing.

5. In all commercial sheet steels the physical characteristics are well above the service requirements.

The commercial testing of sheet steel for electrical purposes, therefore, resolves itself into:

a. Chemical tests to determine the composition of the steel.

b. Electrical tests to determine the losses in the steel after punching, before and after annealing.

c. Electrical tests to determine whether aging, or increase in the losses, occurs when the steel is subjected to moderate temperatures.

d. Tests for permeability.

Chemical Tests. — Sheet steel used for electrical purposes is always a very mild steel, the carbon rarely being above 0.15 per cent; the phosphorus, sulphur, silicon and manganese also usually being kept quite low. The composition may vary over comparatively wide limits and the steel still fulfill the necessary conditions as to quality. One or two complete analyses from each heat, and occasional check analyses from the sheet before and after annealing, are usually sufficient for the purpose.

Electrical Tests. — By far the most important tests are those to determine the hysteresis and eddy-current losses, either separately or combined, the amount of these losses showing the electrical quality of the steel.

Hysteresis Loss. — Hysteresis loss may be defined as the work done in reversing the magnetism in the steel, and it may be considered as the molecular friction due to the reversal of the

magnetism, this friction manifesting itself as heat. The amount of hysteresis in a given steel varies with the composition, with the hardness, with the maximum induction at which the steel is worked, with the frequency of reversal of magnetism, with the wave form of the applied electromotive force used in the test, and with the temperature of the test sample. The hysteresis loss is greater, as a rule, in hard steels than in soft steels. It varies approximately as the 1.6 power of the induction, and directly as the frequency. It is greater with a flat top or a sine-wave electromotive force than with a peaked or a saw-toothed wave.

Several instruments have been devised for measuring the hysteresis loss in steel The Ewing hysteresis meter is probably the best known and most used. With this instrument samples weighing only a few ounces are required for the test, the measurements being made at a fixed induction and the instrument calibrated so as to read direct in some convenient unit. A complete description of this instrument and the method of its working may be found in the "Journal of the Institution of Electrical Engineers" (London), Vol. XXIV, page 398. Other instruments employing the same general principle or entirely different methods are available for measuring hysteresis loss, but as these may all be found in the text books of the day their description will not be given here.

Hysteresis measurements are valuable as showing the effects of annealing, but as it is very difficult in practice to separate the hysteresis loss from the eddy-current loss, and as the total loss under working conditions is the point of vital importance to the user of the steel, measurements of hysteresis loss alone become, in general, of secondary importance.

Eddy-Current Loss. — By eddy-current loss is meant the loss due to the circulation of electric currents in the sheets themselves and between the adjacent sheets, due to the steel acting as a conductor in an alternating magnetic field. The eddy-current loss varies inversely as the ohmic resistance, directly as the square of the induction, and decreases as the temperature increases. It is greater in thick sheets than in thin sheets, and is greater as the insulation between adjacent sheets is less. Tests for eddy-current loss alone are difficult to make, and, as far as the writer is aware, no instrument has been devised for this purpose. An approximation of the amount of eddy-current loss in a given sample can be

reached by measuring the total losses at different inductions and assuming that the eddy-current loss varies as the square of the induction and the hysteresis loss as the 1.6 power of the induction. For special investigations the eddy-current loss is sometimes calculated in this way, but commercially such tests are rarely considered.

The measurement of the total losses under working conditions gives the best index of the electrical quality of the steel. As the total loss is made up of the combined hysteresis and eddy-current losses, it is subject to all the variations of each as outlined above.

Measurement of Total Losses. — In commercial routine testing, as followed out in the sheet steel testing department of the Westinghouse Electric & Manufacturing Company, of which the writer has charge, two separate methods, which may be designated as the transformer method and the armature method, have been found very satisfactory. In both these methods of testing commercial conditions of operation have been aimed at, in order that the results obtained might be checked with the tests made on similar material in commercial apparatus. The test samples have also been so chosen that they will be available for commercial apparatus later, this effecting a considerable saving of material where many tests are made.

The transformer method has been so called for the reason that the test sample consists of about ten pounds of punchings of a standard transformer plate, these punchings being built up in the same manner as when used in the transformer. For convenience in handling and winding the test sample a block carrying the coil has been devised, this block being split and the wires of the coil continued between the two parts by means of mercury cups and contacts. By this means samples which are built up or plates which are not split may be used and placed on the testing block with the winding in place in a few seconds. The routine tests on such samples consist in measuring the total losses at a given induction and frequency by means of a watt meter. For special tests the induction, frequency, wave form, and the pressure on the sample are varied as desired.

This test is used regularly for judging the quality of each lot of steel as received, for judging the quality of the annealing of each furnace load of material and for determining the aging on all classes of material. From 20 to 50 tests per day are made

on this apparatus by one operator. In making tests of this kind, the wave form of the applied voltage must be known and should preferably be a sine wave; correction must be made for the copper loss in the magnetizing coil; correction must be made for the losses in the volt meter and watt meter, or these losses must be eliminated in the measurements; the test samples must be at approximately uniform temperature.

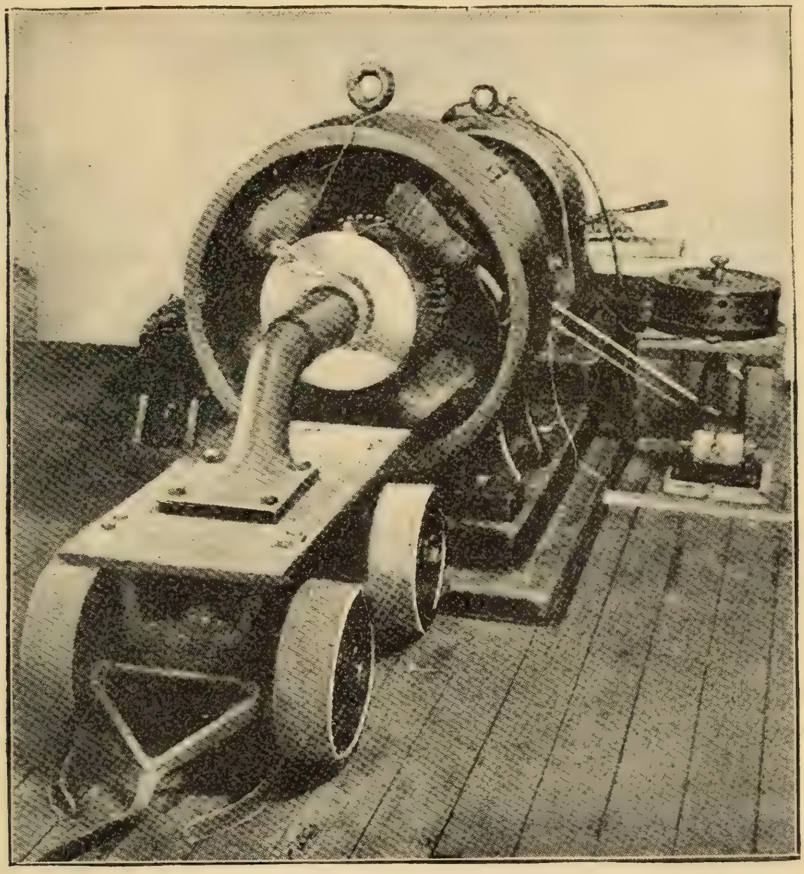

Fig. 1. The Testing Device.

The armature method is so called for the reason that the test sample consists of standard armature punchings, which are revolved in a standard form of dynamo field. The measurements are made by means of a spring dynamometer. A testing device of this kind is illustrated in Fig. 1, and a detail drawing of the dynamometer used for reading the losses is shown in Fig. 2. The general plan of this apparatus is as follows:

A small variable speed direct current motor has a shaft ex-

tension on which the sample is mounted. The speed is read in terms of voltage across the terminals of a small magneto which is belted to the motor shaft and shown to the right in Fig. 1. The test sample is revolved in a field having specially wound field coils and adjustable pole pieces. The extension shaft on which the sample is mounted carries a spring dynamometer, with a special device for reading the deflection on this dynamometer when the sample is in motion. The sleeve which carries the sample is provided with heavy flanges, and is adapted to be placed in an hydraulic press, so that any desired degree of pressure may be reached and maintained on the sample during the test.

The Spring Dynamometer. — The very unique spring dynamometer used in this device was designed by S. M. Kintner and deserves special notice. As will be seen from Fig. 2, the hollow shaft C contains a spiral spring, J, the inner end H being rigidly held to the shaft, while the outer end is fastened to the sleeve A, on which the sample is mounted. The shaft carries a pointer, E. and the sleeve a circular disk, D, approximately eight inches in diameter, graduated on its beveled face in a uniform scale to small divisions. In close proximity to the scale is placed a spark gap, G, which is in series with the secondary of the induction coil, S. The primary of the induction coil is connected to a contact device on the motor shaft, the break point being exactly in line with the pointer E. Leyden jars are used across the secondary of the induction coil to cut down the duration of the spark. The scale and the pointer are shielded from the light of the room, and a tube, F, is provided for observing the scale and pointer at the exact angular position occupied when the spark passes across the air gap, illuminating the scale and pointer for an instant at each revolution of the shaft. By this means it is perfectly feasible to read to a high degree of accuracy the deflection of the spring when the scale and pointer are both revolving at a speed of from 1,000 to 2,000 revolutions per minute. The bearing between the sleeve and shaft is nicely ground and well lubricated, so that there is practically no friction whatever when the test sample is in motion. The apparatus is calibrated by measuring the torque on the spring for an observed deflection. The loss in the sample is then measured in terms of torque and speed, reducing this, if necessary, to the ordinary units of watts per pound in the test sample. For comparative work this reduction is not necessary.

By varying the field strength, the air gap, the form of pole pieces, the speed and the pressure on the sample, tests under a wide range of conditions are obtained. The windage may be measured by taking readings on the dynamometer with no current in the field. In special tests complete curves are taken at varying speeds and field currents. In routine tests only a few points are taken.

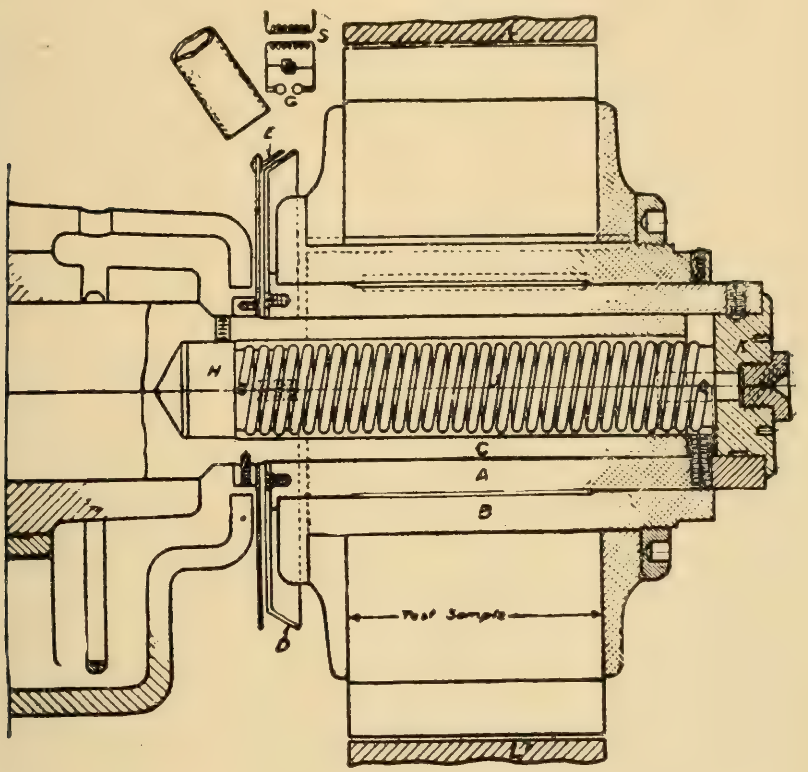

Fig. 2. Sectional View of the Dynamometer for Measuring Armature Losses.

For convenience in handling the samples, which together with the sleeve weigh approximately 125 pounds, a special truck, shown in the foreground, Fig. 1, has been devised, by means of which the sample can be carried about and very quickly placed in position on the testing shaft with a minimum amount of labor.

The above apparatus is used for determining the quality of armature steel as received and the quality of the annealing. It forms a most convenient method of studying the variation in armature losses due to varying conditions, such as pressure, insulation between sheets, variation in induction, variation in form of armature slot, etc. The actual induction may be measured by means

of a special coil slipped on the armature punching, the leads of which are brought out to a contact device mounted on the special truck used for carrying the test samples. The device has been in constant use for several months, and has been found so satisfactory that it may be confidently recommended to those desiring to make similar tests.

Test for Aging. — It was discovered about ten years ago that when sheet steel is annealed so as to have a low loss and then subjected to a temperature of from 80° to 100° C. the loss sometimes increases, in some special cases this increase being as much as 100 per cent in ten days. Fortunately such cases are rare, and ordinarily the increase is small or there is no change whatever in the loss.

As the aging depends on the kind of material used and on the heat treatment to which it has been subjected, it becomes very desirable to make regular routine aging tests on all steel used for electrical purposes. This is all the more necessary as it is practically impossible to always get steel which has been subjected to identical treatments. These aging tests consist merely in repeating the measurements for total losses at certain definite periods of time after the initial tests, the sample being subjected in the interim to the aging temperature. Tests after ten days and after thirty days in the aging oven usually give the necessary data for judging the quality of the material. For purpose of investigation longer tests are frequently necessary, especially when the effect of temperatures lower than the regular aging temperature is desired. In the tests with which the author is familiar aging tests are frequently run for six months or a year, and some special tests have been in progress for approximately ten years.

The transformer samples are usually used for the aging tests, on account of there being less material to handle and the tests being more easily made than with the armature samples.

The aging oven used for these tests consists of a large wooden box, covered on the outside with galvanized iron and lined with asbestos. Steam coils are located at the bottom and ventilators are provided at the top and bottom, so that a slight circulation of air may be secured to equalize the temperature. Steam at 150 to 180 pounds pressure is used for heating. The oven is divided into two parts, one of which runs normally at a temperature of very approximately 95° C. and the other at 60° to 65° C.

These temperatures are maintained year in and year out, and the oven usually contains from 100 to 200 samples which are undergoing the aging test. The temperatures mentioned were selected for the reason that the higher temperature is comparatively easy to maintain and gives comparatively rapid aging when a material is found which is subject to aging, and the lower temperature represents very approximately the temperature at which ordinary electrical apparatus will run under normal working conditions.

Permeability Tests. — As stated earlier in this paper, the permeability of sheet steels used for electrical purposes varies over comparatively small limits, and the exact permeability of a particular sample is ordinarily not of great importance. It is not customary, therefore, to make routine tests for permeability. Occasional tests are advisable, however, and for this purpose a modi-

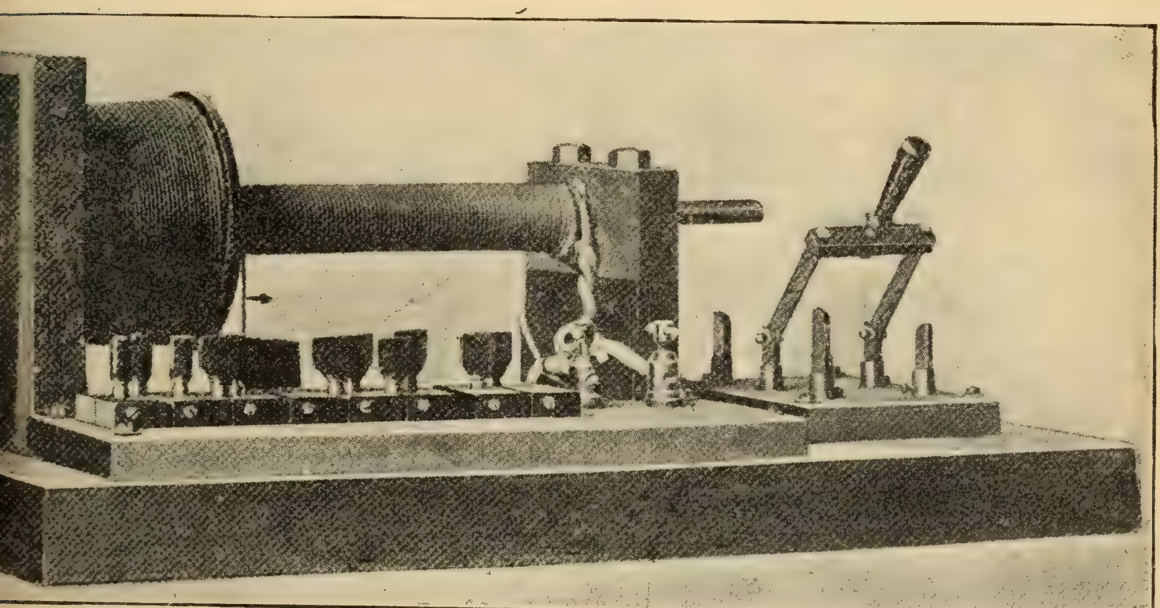

Fig. 3.

fied permeability meter, designed by Messrs. Lamb & Walker and described in the "Journal of the Institution of Electrical Engineers" (London), Vol. XXX, page 930, is generally used. This instrument, arranged for measuring solid material in the form of round bars, is shown in Fig. 3. For measuring sheet steel the form of the coil and sample holders is changed so as to take rectangular sections. Strips of steel to be measured are sheared to the proper dimensions and clamped in blocks made for the pur-

pose, the measurements being made exactly as in the case of solid material. With this instrument a complete permeability curve with hysteresis loop may be taken in a comparatively short time. The accuracy is not as great as with the well-known ballistic method, but it is sufficiently accurate for the purpose and the tests are much easier to make.

The intention of this paper has been to bring before the society some methods of testing which are in daily use, and which have been found very satisfactory for the purpose for which they are intended. They are not laboratory methods, as the term is usually understood, but they are capable of giving valuable results from an investigation standpoint, as the results obtained may be applied directly to commercial apparatus. It is evident that any work that can be done to reduce the losses in electrical steel and prevent aging when the losses are reduced will be of great value to all manufacturers and users of electrical apparatus.

PERMEABILITY OF CAST STEEL*

By H. E. DILLER

IT was formerly thought that pure iron was more permeable than any of the commercial steels, or any special alloy which could be made with iron. This assumption has lately been disputed and the claim put forth that the addition of silicon, phosphorus and aluminium to steel increases the permeability of the metal. However, at present it is the general rule among foundries making steel castings for dynamos and motors to try for about the following composition: Silicon 0.10, sulphur below 0.07, phosphorus below 0.07, manganese below 0.05, and carbon below 0.10. In order to find out more about the effect

* Read at the Atlantic City meeting (June, 1904) of the American Society for Testing Materials.

of small quantities of the different elements on the permeability of cast steel I got a set of bars, the first of which conformed to the above composition and each of the others varied from it in only one element. These bars were made with much care by the George H. Smith Steel Casting Company, of Milwaukee, who use the converter process. There were two bars in each set and the results reported are in all cases the average of two bars.

The values given are, I believe, absolute. They are at least relative. The bar and yoke method was used in making the permeability tests. The bars were one inch in diameter, and the mean magnetic path through the bar was thirty (30) centimeters long. The yoke was made of laminated steel, with a cross section 4½ inches square. The secondary coil of eight turns was right next to the middle of the bar, inside of the primary coil of 1,500 turns. The constant of the galvanometer was taken with a standard solenoid, having a primary coil of 739 turns and 160 centimeters long. Its secondary coil had 500 turns.

The reason for describing the method used for making these tests is that there is a great variation of results when compared to the curve of the Smith Steel made by a western university. These results differ so widely, especially at 10 H, that I give them in the table. On the other hand, my results on another cast steel checked within from one to three per cent of a curve made from that steel by an eastern technical college. These variations would seem to indicate the advisability of not only a standard method, but if the bar and yoke method is used, a standard sized bar, yoke and standardizing solenoid. And this society could do a good work in formulating such standards.

On the following page is a table of the results obtained in terms of H and B to the square centimeter. The normal bar shows as good as any bar of commercial steel I have tested, so in comparing these results with those obtained by other methods it will be well to consider the normal bar as somewhat above the average dynamo steel. The analysis of the normal bar is: Silicon 0.10, sulphur 0.06, phosphorus 0.06, manganese traces, carbon 0.09.

The annealing increased the permeability in all the bars, especially in those containing a high percentage of carbon or of manganese, but the increase was much the greatest at the lower densities. The increase of B in the normal was three per cent at 10 H and 1.3 per cent at 20 H. Probably in a heavier casting,

Table of Results of Permeability Tests

	10 H		20 H		40 H	
	Unannealed	Annealed	Unannealed	Annealed	Unannealed	Annealed
College Results of Normal Bar...	13,600	......	14,850	......	15,760	......
Normal Bar......	11,310	11,650	14,670	14,870	16,160	16,200
Carbon 0.32......	8,750	9,550	12,050	12,730	14,440	14,860
Carbon 0.43......	7,580	8,620	11,880	12,730	14,440	14,870
Manganese 0.43..	10,810	11,580	14,080	14,690	15,710	16,100
Manganese 0.65..	10,280	11,270	13,590	14,440	15,460	15,960
Manganese 0.95..	9,660	10,700	13,020	14,040	15,170	15,730
Silicon 0.43......	10,960	11,710	14,160	14,760	15,920	16,150
Silicon 0.54......	11,590	11,890	14,220	14,550	15,660	15,900
Phosphorus 0.17..	11,330	11,910	14,190	14,630	15,660	15,950
Phosphorus 0.27..	11,860	12,010	14,460	14,690	15,620	15,920
Aluminium 0.93..	11,660	11,890	13,880	14,140	15,190	15,410

which would necessarily cool slower, the annealing would have even less effect.

The carbon and manganese, as might be supposed, have a very harmful effect on the permeability, but 0.43 per cent of manganese lowered B of the annealed steel only one per cent. This seems rather strange in view of the strong effect manganese has in lowering the permeability of cast iron.

Phosphorus, silicon and aluminium did increase the permeability but only to small extent at 10 H, while at 20 H and at 40 H the normal bar has a higher permeability than any of the other bars. In this connection of an increase at the lower, and a decrease at the higher densities an experiment with cast iron may be of interest.

A bar 17¾ inches long and 1⅛ inches in diameter was heated and allowed to cool twelve (12) times, according to Mr. Outerbridge's recently published experiments. The bar increased to 18¼ inches in length and to 1 9-64 inches in diameter. The following are the B and H values:

	15 H	30 H	60 H
Before Annealing, B............	3,480	5,670	6,640
After Annealing, B.............	3,590	4,480	5,610

The results given from the steel bars would indicate that a substantial increase in permeability cannot be gained in additions of silicon or aluminium unless they are added to the extent

of several per cent, and even then it is doubtful whether there would be an increase in permeability above 20 H. Considerably more than two per cent of phosphorus would be required to effect the permeability to a marked degree. But at least it seems safe to remove the upper limits for these three elements in specifications for cast steel for dynamo work, so far as their effect on the permeability is concerned.

TEST FOR BRITTLENESS IN STRUCTURAL STEEL*

By J. P. SNOW

IT is felt by many users of structural steel that mill inspectors should give more attention than is now usual to the detection of brittleness in our bridge material. Brittleness may be due to improper heat treatment or to segregated carbon or phosphorus. These defects may occur in material rolled from part of the slabs derived from a given ingot, while material rolled from the same melt or even from other slabs of the same ingot may be exceptionally good. If the ordinary tensile and bending tests of the heat from which the material in question is derived should be taken from those parts where objectionable segregation had not occurred and which had received proper heat treatment, the results would not expose the brittle features of the part supposed to be bad.

The desideratum is a practical method of testing, which will furnish the inspector a means of detecting brittleness in any piece that comes from the rolls that he suspects may be objectionable. The object of this paper is to suggest a scheme which seems to me to answer this requirement. Prime essentials of a test of this sort are simplicity and quickness of accomplishment. Mill men say, with reason, that they cannot hold stock until machine finished samples can be prepared and elaborate tests made. I am informed that much of the material now being used is many miles from the mill, on its way to the fabrication shop before the testing machine work is done on the specimens that are supposed to determine whether the material is to be accepted or rejected.

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* Read at the Atlantic City meeting (June, 1904) of the American Society for Testing Materials.

Determining the temperature of the metal after or before the last pass through the rolls is neither efficient, precise, nor conclusive. Delaying the piece before the last pass until the right temperature is reached refines only the outer skin of the material. It is not the function of buyers to tell the manufacturer how he shall produce his steel or at what temperature he shall roll it, but rather to ascertain if the product which he offers is suitable for their uses. This can be best accomplished by testing the finished product in a direct way.

The scheme herein proposed is in substance a nicked bending test on crop ends of plates and shapes as they are trimmed at the rolling mill for shipment. A nicked bend is proposed because the object is not so much to see if the specimen will bend without fracture, as to open up the grain of the steel to see whether it is fine and silky or coarse and crystalline.

It is proposed to take a generously wide piece of crop end so that the effect of the shear at the edges will not affect the result. It is deemed unfair to the manufacturer to depend upon narrow sheared specimens for this scheme of bending, because the injurious effect of the shear should not be assessed against the quality of the steel. Punched specimens are ruled out for the same reason. If narrow specimens with milled edges or punched specimens with reamed holes are used, the vital element of quickness of accomplishment is lost; for, while the specimens are awaiting their turn at the finishing machine the plate or shape from which they are cut is loaded for shipment or covered up in a pile of other stock. The scheme proposed will tell its story, if desired, before the rolling heat has left the piece. It can be executed and a decision reached, almost as quickly as the surface inspection of a plate can be made.

In detail the scheme is: to shear from the crop end a piece, say 12 inches wide, and nick it about three inches from one edge, preferably across the direction of the rolling, with a tool made for that particular thickness; clamp it in a hydraulic vise, and bend the free end over by power. The sketch shows in outline a possible bending vise. Both the vise and bending roller are to be actuated by hydraulic power which is always available in a rolling mill. The nick is proposed to be made with a tool like a blacksmith's flatter, having a raised bead on its face.

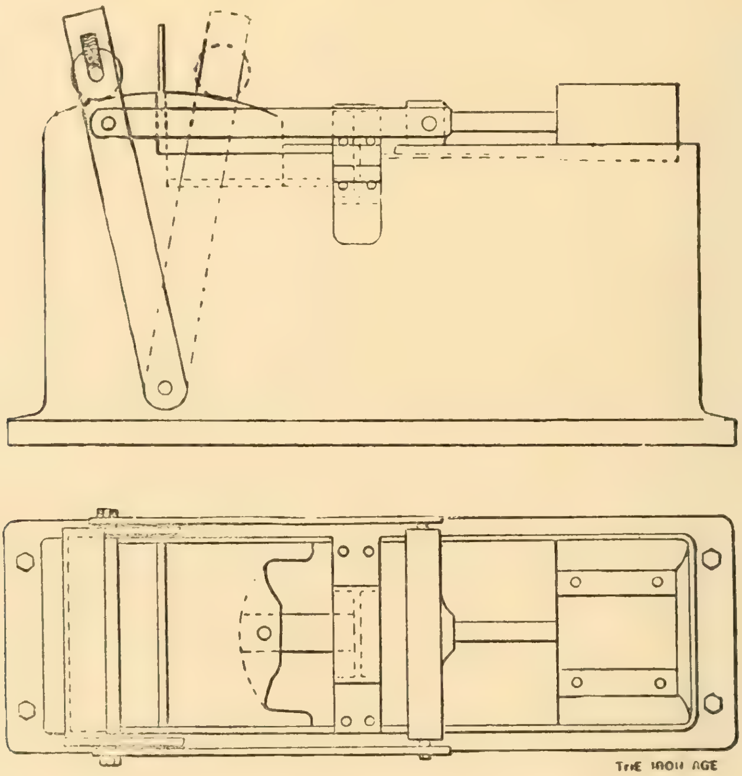
Nicked bending tests by impact have been recommended in the past by many investigators. In 1892, Le Chatelier advocated such tests before the French Committee on Methods of Testing, and since that time work on these lines has been done by Barba, Considere, Le Blant, Aucher, Frémont, Osmond and Charpy in Europe and by S. Bent Russell and others in this country. All of these experimenters sought to determine the resilience of the material by impact tests, thinking to replace the ordinary tensile tests by these determinations. But as shown in Johnson's "Materials of Construction," impact testing is surrounded by so many uncertainties that it has never been found commercially practicable for structural materials. Evidently the constant effort has been to make the test prove too much. In the scheme herein advocated the object is not a complete physical test of the material but simply an examination of the grain, as shown in the fracture, to ascertain if the material is brittle from any cause.

To insure a fracture in ductile material, the deformation must be localized by a nick. The form of the nick, its depth and shape must be determined by experiment, but for a beginning it is suggested that a depth of one-eighth the specimen be tried, the bead with which the nick is made to have the form of the Whitworth screw thread. Investigation may show that a single size of nick may be used for different thicknesses, but it is probable that each thickness should have its particular size. The nicking die may be struck by hand hammers, or a light quick acting steam hammer may be provided for the purpose.

As to the method of producing the deformation it is possible that the distinctive difference between material that is good enough to be accepted and that which ought to be rejected cannot be brought out by making the bend with a press. It may be necessary to use impact, as was done by Fremont in a series of experiments described by him at the Budapest meeting of the European Railway Congress. These experiments show that a ductile steel may be broken short off by a blow of sufficient velocity. We know that ordinary structural steel when nicked and bent will invariably break unless it is exceptionally ductile and in very narrow specimens; hence it seems that a press bend on a wide specimen will certainly produce a break and show up the grain. A press bend if effective is preferable to a blow, on account of its more certain action and because it does not need

adjustment for different thicknesses as would be needed if the bending was done by a blow.

It is believed that a test of this kind will expose coarse grain in steel, due to improper heat treatment, segregation, bad chemistry or any other defect that tends to brittleness. The engineer may, under present specifications, demand certain chemical and physical qualities when buying steel. He may not be justified in prescribing the exact ratios of the many " ites " or the precise



Plan and Elevation for Vise for Bending Test.

" eutectic values " of the various compounds that enter into the material which the manufacturer gives him for steel, but he may reasonably demand simple tests like that advocated here to satisfy himself that the material is free from brittleness.

In the past, when puddled iron was the usual structural material, engineers depended largely upon bending tests to ascertain the quality of the output of the mills. Mr. C. C. Schneider has told me that he cared little for the tensile strength, elongation and other physical features of wrought iron as determined by the testing machine, but that he set great value on cold bending tests

of scrap ends. Sir Benjamin Baker, when engaged upon the Forth bridge stated that he placed more reliance upon bending tests of mild steel than upon testing machine determination. With the steel of the present day we must test for ultimate strength to secure a grade that can safely undergo the ordinary shop manipulations and examine the chemistry to secure uniform composition, but have we not too much lost sight of the valuable old time feature of bending? The ordinary plain bending will not always show us the grain of the steel. In fact the width of the specimen and the radius of the bend are so selected in our usual specification that ordinarily good material will bend without fracture. Its ability to do this is the gauge for acceptance. To this end the sheared edges are planed, which defeats the very purpose of the test desired on account of the time involved in the operation. Moreover we bend but one specimen for each melt, which assuredly does not attempt to control the rolling heat.

It is true that the proposed test may involve closer attendance of the inspector at the mill than our usual commercial testing requires, and it may be impossible to define the lines by which an inspector shall be governed in rejecting material, as sharply as can be done under our present system, but the inspectors' attendance can be arranged for and the results reached by Frémont give us a clew to what may prove to be a proper criterion for acceptance or rejection.

Frémont's paper shows that when a specimen of non-ductile material is bent, a hardened ellipse tends to form on the compression side which acts as a heel around which the fibers on the tension side have to stretch. If the specimen is nicked, this stretch is localized and confined to the fibers at the bottom of the nick, and breaking is sure to occur as is explained in detail by Frémont. If the material is somewhat ductile and the specimen narrow, the compressed metal flows outward. This flowing out assists compression and tends to decrease the stretch required on the tension side by removing the heel farther from the tension face, and hence helps toward a gradual break instead of a short one. This consideration explains the well-known fact that wide specimens will not bend so successfully as narrow ones.

If in the proposed nicked bend the specimen should break around Frémont's "ellipse of enlargement," instead of square across; or if it did not break clear through, we could safely con-

clude that the material was not brittle. If the break was square across and the fracture silky or but partly granular, we could presume that the heat treatment was good and segregation not excessive; but if the fracture showed crystalline facets or appeared dull and cokey it would be ground for rejection. After sufficient careful experimenting I am sure that workable limits can be fixed upon for the guidance of inspectors. It is possible that thick and thin material cannot be brought to follow the same law, but rules can be established for varying thicknesses. Material that is known to be good and that which is known to be bad, both from overheating and segregation, can be experimented upon and safe extremes established.

Metallurgical literature is filled at present with complaints of poor structure in rails and to some extent in other steels. The complaint is not quite so common in regard to structural steel, for the reason, probably, that it is usually in thin sections which cool to a lower temperature than thick ones, while passing the rolls. It is the case, however, that rolled beams have sometimes proved so brittle and untrustworthy that some engineers dislike to use them in railroad bridges. It is likely that the principal reason for this condition is too high heat during the rolling, due to their heavy section. If the crop ends of such beams are sheared up so that a section of the web or flange can be nicked and bent in the proposed machine the coarse structure, if it exists, will surely be exposed and the beam saved from discrediting its species when put into service.

A similar test on crop ends of rails could be made with the rails while passing the straightening press and many of those having coarse structure at center of head, open grain, lamination, pipes, sulphur flaws or other defects that one drop test in five heats does not detect, would be saved from going into the track and causing trouble for both user and manufacturer.

The above scheme of testing is submitted for consideration by our members. It is intended to supplement the usual tests for physical qualities and is suggested as a means of satisfying buyers of steel that their material is sound and free from brittleness. It is cheap in installation and operation and requires the inspector's continuous attendance at the shearing end of the rolling mill where he belongs. If properly executed it should tend to allay the

agitation that is now going on among users of rails and structural steel in regard to heat treatment, open grain and other rolling mill defects. If the scheme is objectionable to manufacturers it is respectfully offered for their free criticism.

TESTS FOR DETECTING BRITTLE STEEL*

By W. R. WEBSTER

ALL engineers aim to avoid the use of brittle steel in their structures. They have, very properly, specified such chemical limits as will eliminate this trouble in steel from segregation. This course has been followed in this country for years and does not need further comment.

Most of the steel now made will meet all the requirements of the specifications in general use, with a large margin to spare. This has given a false sense of security and too many chances are being taken. In some cases the cold bending tests have been omitted on boiler steel and the material accepted on the results of tension tests alone. Hundreds of boilers are made every year under these conditions. Every now and then a plate fails in shop work and samples taken from such plates will generally not bend flat cold, or anywhere near it. We have no means of learning how many other brittle plates, which do not fail in shop work, are put in boilers. The failures generally occur in thick material, and in most cases, the ordinary cold bending test as called for in our specifications would have detected the brittleness.

There are other cases where axles, rails, etc., are put in service without any physical tests whatever being made. This is directly contrary to the specifications adopted by this society and the opinions expressed in the discussions at our meetings.

Some think that heat always has a softening effect on steel, as in annealing, and that the hotter the steel is finished in rolling or forging, the softer it will be. On the contrary, under such conditions, heat has a hardening effect and is one cause of

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* Read at the Atlantic City meeting (June, 1904) of the American Society for Testing Materials.

brittle steel. The laboratory experiments on the effect of heat have been confirmed by the results obtained from large masses of steel. Steel finished too hot in rolling or forging will have a large grain and will fail under the ordinary cold bending and drop tests. The engineer cannot ignore this any more than he could ignore the effect of chemical composition. Under these conditions is it not proper and just that he demand of the maker some assurance that his steel is finished at the proper temperature and not at any old temperature? It is, of course, preferable to prevent, if possible, steel being made brittle than to take the chances of its being detected after it has been made brittle.

This society took a decided step in the right direction in specifying that cold bends shall be made on each heat of steel in the condition it leaves the rolls. This has been more clearly defined by the Committee on Iron and Steel Structures of the American Railway Engineering and Maintenance of Way Association, in their specifications, as follows: "Full-sized material for eye-bars and other material one inch thick and over, tested as rolled, shall bend cold 180° around a pin the diameter of which is equal to twice the thickness of the bar without fracture on outside of bend." This requirement has been put in general use and necessitates the bars being finished in rolling at a lower temperature, and large eye-bars are now made which meet the requirements of full-sized test very much better than formerly.

All of our present specifications make concessions in the requirements for the heavy material, and it is a question if we have not gone too far in that direction, as it assumes that such heavy material will, of necessity, be finished at a much higher temperature than the lighter material. It also does not induce the maker to improve his methods. The necessary improvement in the present methods which would be required to finish the heavy material at the proper temperature would decrease output and increase cost of such heavy material. Is the consumer willing to pay more for a better material? If so, the maker would, no doubt, meet him half way.

It will not be necessary to adopt any of the more elaborate tests which have been suggested to detect brittle steel if the fin-

ishing temperature is properly controlled and wide cold bends made of full thickness of material rolled. But in the case of forgings, castings, and other very heavy material, annealing will have to be more generally introduced.

THE CLASSIFICATION OF IRON AND STEEL*

By ALBERT SAUVEUR

METALLIC iron is obtained and used in the arts under three different conditions, namely as wrought iron, steel and cast iron. While cast iron is very highly carburized, wrought iron generally contains very little carbon, and steel a more moderate amount of that element, which amount, moreover, varies according to the grade of the steel, between wide limits. It is to the different proportions of carbon which they contain that these three products of the metallurgy of iron owe their generally very different properties. Cast iron is not malleable and lacks both strength and ductility; it is brittle. Wrought iron, on the contrary, is very malleable, very ductile and fairly strong, while the strength and ductility of steel varies according to its carbon content, the strength increasing and the ductility diminishing with that element. Carburized iron, moreover, containing a sufficient amount of carbon, possesses the invaluable property of becoming intensely hard when suddenly cooled from a high temperature, and, formerly, only those metals which possessed this hardening power were called steel.

While the properties of cast iron, however, are radically different from those of wrought iron, and while the properties of medium high carbon steel are likewise very different both from the properties of cast iron and from those of wrought iron, if we examine the properties of very high carbon steel on the one hand, and of very low carbon steel on the other, we find that the former so much resemble the properties of certain grades of cast iron (white cast iron), and that the latter are so similar to

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* Read at the Atlantic City meeting (June, 1904) of the American Society for Testing Materials.

those of wrought iron, that a sharp distinction between these three metals founded upon their properties alone, or upon their composition, is quite impossible. The similarity, not to say identity, in composition and properties, existing between wrought iron and the slightly carburized metal called soft steel, is especially troublesome in any attempt at such a classification.

In order to arrive at any satisfactory nomenclature it is absolutely necessary to take into consideration the method of manufacture by which the metals were obtained. This necessity was recognized by the international committee appointed in 1876 at the instance of the American Institute of Mining Engineers, and which recommended the following classification:

1. That all malleable compounds of iron with its ordinary ingredients which are segregated from pasty masses, or from piles, or from any forms of iron not in a fluid state, and which will not sensibly harden and temper, and which generally resemble what is called "wrought iron," shall be called *weld-iron* (German, *Schweisseisen;* French, *fer soudé*).

2. That such compounds, when they will from any cause harden and temper, and which resemble what is now called "puddled steel," shall be called *weld-steel* (German, *Schweissstahl;* French, *acier soudé*).

3. That all compounded iron with its ordinary ingredients, which have been cast from a fluid state into malleable masses, and which will not sensibly harden by being quenched in water, while at a red heat, shall be called *ingot-iron* (German, *Flusseisen;* French, *fer fondu*).

4. That all such compounds, when they will from any cause so harden, shall be called *ingot-steel* (German, *Flussstahl;* French, *acier fondu*).

In this classification very great preëminence is given to the hardening power of iron containing a sufficient amount of carbon. Indeed, it is made the criterion by which steel shall be distinguished from iron.

A serious objection to this classification is that the hardening power is not acquired abruptly when a certain amount of carbon is present but very gradually as the proportion of that element increases. To draw a sharp line between carburized irons pos-

sessing the hardening power and those lacking that property is an impossible task. These specifications are necessarily silent regarding the nature of the test by which it can be ascertained whether carburized iron is or not sensibly hardened by sudden cooling. The word sensibly is, moreover, altogether too elastic and vague a term to introduce into this nomenclature. Such phrases as "generally resembling what is called wrought iron" may also be condemned on the same ground. The substitution of the term weld-iron in place of the universally adopted name of wrought iron is of questionable wisdom, as well as the introduction of the terms weld-steel, ingot-steel and ingot-iron. This classification only retains an academic interest, for it has never been adopted in actual practice, at least not in English speaking countries nor in France. The name of Flusseisen (ingot-iron), however, has passed into the German metallurgical vocabulary, but even in the German works, where the metal is made, it is called steel.

In English speaking countries and in France there exists an understanding, tacit at least, to give the name of wrought iron to all irons obtained in a pasty condition, and, therefore, mixed with slag, and to reserve the name of steel for all carburized irons obtained in a molten condition, and, therefore, free from slag. In such a classification much importance is attached to the method of manufacture and, therefore, to the absence or presence of slag in the resulting products. It appears to be, on the whole, the best solution of this difficult problem, for it affords a ready means of properly classifying all iron products, even when in ignorance of the processes by which they were obtained, for the presence or absence of slag, which can be so readily and conclusively ascertained under the microscope, will make it possible to assign to the metal its proper place. It seems, however, desirable to distinguish between these slag-bearing irons obtained in a pasty condition and very free from carbon and those which, although produced by the same methods, contain enough carbon to assume a decidedly steely character. The name of *steely wrought iron,* which is not a new one, appears to be a very appropriate one for products of this description, suggesting at once their nature and making it possible to retain the word steel exclusively for products obtained molten.

In view of these considerations the following classification appears to the writer the best that can be devised:

			Usual methods of production
I. Carburized iron obtained in a molten condition and therefore free from slag	1. Not malleable	*Cast Iron* (gray, mottled, white)	Blast Furnace
	2. Malleable	*Steel*	Bessemer Process Open-Hearth Process Crucible Process
		Malleable Cast Iron (white cast iron made malleable by conversion of combined C into temper C . . .	Malleable Cast Iron Process
II. Iron obtained in a pasty condition and therefore containing slag	1. Containing less than 0.25 per cent C, *Wrought Iron* . . .		Direct Processes (Catalan, Bloomeries, etc.), Fineries, Puddling
	2. Containing over 0.25 per cent C, *Steely Wrought Iron* . .		
	3. Iron carburized by cementation *Cemented or Blister Steel* . .		Cementation Process

In the appendix accompanying this paper other classifications are reproduced as well as the opinions and comments of several authoritative writers.

As Secretary of Commission 24 of the International Association for Testing Materials, appointed to study the uniform nomenclature of iron and steel, the writer hopes that this short paper will lead other metallurgists and engineers to contribute to the discussion of this question.

APPENDIX

General Classification Proposed by Professor Henry M. Howe

The following classification proposed by Professor Henry M. Howe is described at length in his "Iron, Steel and Other Alloys":

General Classification of Iron and Steel

<table>
<tr><th colspan="2"></th><th>With Very Little Carbon</th><th>With a Moderate Amount of Carbon</th><th colspan="2">With Much Carbon</th></tr>
<tr><td colspan="2">Slag-bearing or Weld-metal Series</td><td>WROUGHT IRON
PUDDLED IRON
BLOOMARY OR CHARCOAL IRON</td><td>Weld Steel
Puddled Steel
Blister Steel</td><td colspan="2"></td></tr>
<tr><td rowspan="3">Slagless or Ingot-metal Series</td><td rowspan="2">Normal or Carbon Group</td><td rowspan="2">Soft Steel or Ingot Iron
Bessemer
Open-Hearth
Crucible (Mitis)</td><td colspan="3">MALLEABLE CAST IRON</td></tr>
<tr><td>Half-hard and Hard Normal or Carbon Steel
Bessemer
Open-Hearth
Crucible</td><td colspan="2">NORMAL CAST IRON
WHITE, MOTTLED, GRAY, SILVERY, WASHED-METAL</td></tr>
<tr><td>Alloy Group</td><td></td><td>Alloy Steels
Nickel Steel
Tungsten Steel
Manganese Steel
Chrome Steel
Silicon Steel</td><td colspan="2">ALLOY CAST IRONS
FERRO-TUNGSTEN
FERRO-MANGANESE
FERRO-CHROME
FERRO-SILICON
SILICO-SPIEGEL</td></tr>
<tr><td colspan="2">Per Cent Carbon</td><td>0 to 0.3</td><td>0.3 to 2.0</td><td>2.0 to 4.5</td><td>to 6.0</td></tr>
</table>

Note. — In order to make this table clearer, a special type is used for each of the three great classes, wrought iron, steel and cast iron. The wrought iron is given in Roman capitals, all the different varieties of steel in Italics, and all the different varieties of cast iron in Roman small capitals.

The American Nomenclature of Iron Products — By H. H. Campbell

In his recent book on the "Manufacture and Properties of Iron and Steel," H. H. Campbell comments as follows on the "American Nomenclature of Iron and Steel":

The classification by hardening is a dead issue in our country. It had quietly passed away unnoticed and unknown before the Committee of the Mining Engineers had met, and the best efforts of that brilliant galaxy of talent could only pronounce a kindly eulogy.

Strictly speaking, some mention must be made of hardening in a complete and perfect definition, for it is possible to make steel in a puddling furnace by taking out the viscous mass before it has been completely decarburized; but this crude and unusual method is now a relic of the past, and may be entirely neglected in practical discussion. No attempt will be made here to give an ironclad formula, but the following statements portray the current usage in our country:

(1) By the term wrought iron is meant the product of the puddle furnace or the sinking fire.

(2) By the term steel is meant the product of the cementation process, or the malleable compounds of iron made in the crucible, the converter, or the open-hearth furnace.

This nomenclature is not founded on the resolutions of committees or of societies. It is the natural outgrowth of business and of fact, and has been made mandatory by the highest of all statutes — the law of common sense. It is the universal system among engineers, not only in America, but in England and in France. In other lands the authority of famous names backed by conservatism and governmental prerogative, has fixed for the present, in metallurgical literature, a list of terms which I have tried to show is not only deficient, but fundamentally false.

On the Definitions of Pig Iron, Wrought Iron and Steel — A. Pourcel, International Association for the Testing of Materials

Perhaps the time has arrived to realize the wish expressed at the Düsseldorf meeting in 1880, by the lamented Dr. W. Siemens ("Journal of the Iron and Steel Institute," 1880, Vol.

II, page 439) to establish a general understanding on what ought to be called *wrought iron,* and what *steel.*

It is in the hope of attaining this object that the present note, which has been drawn up by the author as one of a sub-committee of the French Commission for the Study of Methods of Testing, is offered for discussion by the International Congress on Methods of Testing.

Inquiry into Certain Definitions. — Iron is used associated with carbon, and according to the degree of carboration serves the most multifarious uses.

It is impossible to separate very sharply the different classes of its compounds; it is usual, however, to divide their long series into three parts: *pig iron, steel* and *wrought iron.*

Pig Iron. — This is the raw product in the cast state of the reduction of iron ores. The proportion of the bodies other than iron, and amongst which carbon generally predominates, reaches a variable amount. The melting point varies between 1,050° and 1,300° centigrade.

Pig iron cannot be forged. Sometimes, however, it is enabled to acquire, "to a certain extent," the property of undergoing work by the hammer; then we have malleable cast iron, in which an important part of the carbon is in the state of invisible graphite.

Steel and Wrought Iron. — These products are distinguished from pig iron by containing as a rule less of carbon* and foreign bodies other than iron; by being malleable, and having a melting point between 1,200° and 1,500° centigrade. But there are different opinions as to what should be called properly *steel* on the one hand, and *wrought iron* on the other.

First Opinion. — From the chemical standpoint, there are included under the name of *steel,* in the strict sense of the word, the malleable compounds of iron having a certain content of carbon, and which are characterized by the extreme hardness which they acquire by quenching. Under the name *wrought iron* are included the malleable compounds of iron having a smaller

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* Many white pig irons contain only 1.4 per cent to 1.8 per cent of carbon; natural steels contain 1.6 per cent to 2 per cent. The natural steels are produced in Styria, Westphalia, and other parts of the South of Europe by the partial decarburization of pig iron on the finery.

content of carbon, often quite as hard "as non-quenched steels," but not capable of being hardened to the same extent by quenching.

Second Opinion. — It has been proposed to call:

Wrought iron every iron product which is malleable and formed by welding;

Steel every iron product which is malleable and has passed through the fused condition.

In this connection the great influence of fusion has been justly remarked upon. In *welded iron* products formed of elements more or less carburized, cinder is always found between the grains of the metal; the quality of the product also depends in a great measure on the workman.

The iron products which have passed through the fused state are obtained at a high temperature; there is complete liquation between cinder and metal. The elementary (or constituent) bodies formed by cooling are welded together without the interposition of cinder. The quality of the product in this case does not depend on the skill of the workman, but on the quality of the raw materials. The resulting metal possesses those peculiar properties which explain why American, English, Belgian, French and other metallurgists have adopted the name of *steel* for every iron product which is cast and malleable.

Cast steel is easily recognized by applying the appropriate methods. The structure of *welded iron* is such that the presence of the cinder can be recognized by examining the fracture with naked eye, or with microscope; either directly or after a chemical or mechanical operation; whilst in the cast steel there is no cinder, or if there is, it is of local occurrence.

Mr. Grüner would by no means accept this distinction and raised the following objection to it: "It would be strange if a simple physical operation, fusion, should have on the actual properties and the name of metal a greater influence than its chemical nature."

It may perhaps be observed from what has already been said, that the influence of fusion on the chemical nature of the metal is very considerable all the same.

Third Opinion. — The distinction between wrought iron and steel should be based solely on the property of hardening by quenching or not.

Steels would be those malleable iron products which from any cause whatever harden by quenching.

Wrought iron would comprise those malleable iron products which do not harden sensibly by quenching.

According to the French customs law, the duty on *steel* is only applicable to those steels which harden by quenching.

But the customs tariff contains the following clause:

"The other steels are subject to the same duty as wrought iron, whatever quantity of cinder they may contain."

This phrase clearly points to the admission that there are steels which do not harden by quenching. Nevertheless, the present opinion is that arrived at by the international committee assembled at Philadelphia in 1876, which numbered among its members MM. Lowthian Bell (Sir Lowthian Bell, Bart.) and L. Grüner, the latter as a corresponding member. Wrought iron then being separated from steel by property of *hardening by quenching,* the following distinctions were made:

1. Weld iron, Schweisseisen, fer soudé; Ingot-iron, Flusseisen, fer fondu;

2. Weld steel, Schweissstahl, acier, soudé; Ingot-steel, Flussstahl, acier fondu.

These very divisions are indicated in an official order under date January, 1889, addressed to the German Railway Companies, with the view to establishing uniformity in the nomenclature of materials in wrought iron and steel used in railway work.

It may be as well to observe here that *quenching* is not always considered a means of increasing the hardness of steel.

For, amongst the new steels (which contain other bodies than carbon and iron) some instead of becoming harder by quenching, become easier to work.*

The German official order says:

"The line of demarcation between bodies susceptible of hardening by quenching, and those are not, being very difficult to determine materials having a tensile strain of 50 kilograms per square millimeter (about 32 tons per square inch) and above, shall be considered steel; materials with a lower tensile strain shall be considered iron" (wrought iron).

Fourth Opinion. — The fourth opinion is one that results

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* As the manganese steel and nickel steel.

exactly from the foregoing lines. It consists in taking as the limit of demarcation between wrought iron and steel arbitrary figure expressing the resistance to tensile strain in kilograms per square millimeter.

This classification is the most artificial of all.

Conclusions. — Not one of these definitions gives a precise meaning to the words iron (c. e. wrought iron) and steel, or expresses synthetically the characteristics which distinguish the one product from the other.

Quenching cannot, any more than tensile strain, differentiate iron from steel in cast metal. Quenching always modifies the *deformability* (that is the capacity for undergoing work in the cold state) or the *softness* of the metal; and as regards the tensile strain, that may vary between very large limits according to the temperature at which the test is made.

The distinction between a cast and welded product is the easiest to fix. Such indeed is the opinion of the eminent German metallurgist, Professor A. Ledebur, of the Freiberg School of Mines.

M. Ledebur recognizes that fusion is the characteristic that has been chosen to differentiate *wrought iron* from *steel* not only in America, England, France and other countries (including Sweden and Belgium) but even in Germany itself, where many works bear the name of Stahlwerke (steel works) while at the same time they are making only ingot iron (Flusseisen) which, practically speaking, is incapable of hardening by quenching.

At the International Congress of Engineers held in Chicago in August, 1893, M. Campbell, metallurgist of Steelton, in answer to a remark made by Dr. Wedding of Berlin, gave his formal opinion in the following set terms of the definition given in 1876 by the International Committee for distinguishing *iron* from *steel:* "With all due deference and respect for the group of metallurgists who formulated the system used in Germany and recommended for universal adoption, I have always considered this nomenclature as founded on error and impossible to practice."*

To sum up, the second opinion by which a malleable iron product is called by the name of *steel* when it is cast, and by the name of iron (c. e. wrought iron) when it is welded* although it

* The association of German ironmasters has from the first rejected the definitions relating to iron and steel enunciated in 1876 at Philadelphia by

only gives an incomplete idea of the properties of each of these two products, remains, all the same, the clearest, the most synthetical, and the one which is almost universally employed.*

Blister steel is cemented iron (c. e. wrought iron).

Natural steel is a hard wrought iron not thoroughly refined, like puddled steel. Mechanical work is the means by which it is endeavored to render these products homogeneous.

PRESERVATIVE COATINGS FOR IRON AND STEEL†

S. S. VOORHEES, Chairman of the Committee E, of the American Society for Testing Materials, appointed to study preservative coatings for iron and steel, prefaced his report with the following remarks:

"On account of the wide difference of conditions and requirements demanded of preservative coatings, Committee 'E'

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an International Committee of Metallurgists ("Journal of Iron and Steel Institute," 1878, Vol. II, p. 592), definitions according to which the distinction between wrought iron and steel should be ascribed solely to harden by quenching, as has been described above. But after the success of the Basic Bessemer Process in Germany, the said association rescinded its decision for reasons of commercial interest which no longer exist to-day.

* The words of the Act of Congress (United States) passed on March 3, 1893, are as follows: Provided that all metal produced from iron or its ores, *which is cast and malleable,* of whatever descripton or form, without regard to the percentage of carbon contained therein, whether produced by cementation, or converted, cast, or made from iron or its ores, by the crucible; Bessemer, Pneumatic, Thomas-Gilchrist basic; Siemens-Martin or open-hearth process, or by the equivalent of either, or by the combination of two or more of the processes or their equivalent, or by any fusion or other process which is cast and malleable, excepting what is known as malleable iron castings, shall be *denominated* and *classed as steel.* Dr. W. Siemens at the Düsseldorf meeting expressed the opinion of the English ironmasters on the question in these terms: "England was adhering to the older one of calling by the name of *steel,* all malleable metal *that had passed through the fused condition.*" ("Journal of the Iron and Steel Institute," 1880, page 439.)

† Report of Committee E, presented at the Atlantic City meeting (June, 1904) of the American Society for Testing Materials by Mr. S. S. Voorhees, Chairman of the Committee.

decided to publish in pamphlet form the individual opinions of its members relative to the best methods of testing preservative coatings.

"This compilation of the suggested methods is to be distributed among the paint consumers and producers, and engineers, and also through the columns of the engineering and technical press. The methods are published as received.

"It is the earnest wish of the committee that these methods receive the thoughtful criticism of engineers and paint manufacturers, as well as the members of the committee itself; for it is only by the hearty coöperation of all interested in this important matter, the protection of iron and steel structures, that rational sets of standard requirements can be evolved to meet the many conditions of service.

"It is felt that no one set of standard requirements can be imposed on preservative coatings used to protect steel cars, bridge members, structural steel hidden between plaster and expanded metal on one side and brick or stone curtains on the other, and so on through the widely different conditions and requirements demanded in each special case.

"In general, however, the paint film which remains most impervious to water, and is satisfactory in other respects, will probably afford the best protection. In a recent paper on 'Paints for Protection of Structural Work,'* it was shown that, other things being equal, the finer the particles of the pigment the better the protection, thus emphasizing the necessity for thoroughly impervious coatings.

"A satisfactory test to measure this permeability is of the utmost importance. One method suggested among the following schemes dwells at length on this point, and recommends the use of a film of dextrine beneath the paint coating. On immersion in water, if the paint be pervious the dextrine film will be dissolved and the paint will peel.

"It is possible that the suggested electric insulating values of the same film, tested when dry, and after soaking in some electrolyte, as sodium chloride, may afford a measure of the absorption of water.

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* "Result of an Investigation of Paints for Protection of Structural Work," by Robert Job, "Journal of the Franklin Institute," February, 1904.

"The coating, however, must be impermeable, not only when first applied, but also after exposure. This brings up the vexed question of accelerated tests. These tests aim to give in a short time results comparable to actual service.

"The protection afforded by cement coatings, though of recent introduction and limited application, seems worthy of further investigation. At present this coating requires a moist atmosphere while setting, a condition hard to meet in practice. Its action apparently depends not so much on impenetrability to moisture as on the neutralization of carbon dioxide and acid gases, etc. This action is so different from oil paint films that a comparison of these two types of coatings will be difficult. The committee hopes that this phase of the question will be thoroughly discussed.

"The methods subjoined are the individual schemes proposed by the members of Committee 'E' to test the efficiency of preservative coatings for iron and steel.

"Criticism and discussion should be sent to Joseph F. Walker, Bridgeport, Pennsylvania, the secretary of this committee."

Mr. W. A. Aiken, chairman of the sub-committee, commented as follows:

"Inquiry from the 15 other members of Committee 'E' for suggestions in the line of experience or theory as to the best methods in their individual opinion, resulted in replies from two-thirds of the members and brought out a very general endorsement of the chairman's personal views, that 'service tests' should be very markedly distinguished from 'laboratory tests,' and that some arrangement should be made if possible to divide preservative coatings into groups for specific purposes rather than to examine each and every kind with the idea of realizing a panacea.

"Examination of the various laboratory tests to which the materials which may be selected should be subjected indicates that those for time of drying, porosity, peeling, cracking, etc., are practically uniform. Many suggestions, more or less elaborate, were offered for what may be designated as 'laboratory service tests,' namely accelerated tests, bearing somewhat the same relation to actual 'field service tests' as does the boiling test for cement to the regular long-time test for that material; very good as a corroborative test, but hardly sufficient of itself for classing the material.

"In my opinion, too little stress is generally put upon chemical analyses. In all preservative coatings certain essential ingredients should be found, and while certain others may do no harm, certain others may or will. Consequently I should recommend that this matter be taken up in so far as fixing within certain broad limits the percentage of vehicle and pigment, as well as determining the quality of the former, and certain ingredients in the latter, for each class of coating examined."

The report includes contributions from the following members: C. B. Dudley, the International Acheson Graphite Company, Robert Job, the Joseph Dixon Crucible Company, the Patterson-Sargent Company, A. H. Sabin, C. W. Thompson, M. H. Wickhorst, and the A. Wilhelm Co.

STAY-BOLT IRON*

By H. V. WILLE

THE high pressure and large boilers now used have increased the breakages of stay-bolts, and have given rise to many devices for overcoming the difficulty. The two principal difficulties are: (1) Leakage (2) Breakage. Breakages are caused by the vibration due to unequal expansion of the inside and outside sheets. The object of flexible stay-bolts is to provide for the vibration. Such stay-bolts have not proved altogether satisfactory for the reason that with incrusting waters the ball joint becomes filled with scale and becomes rigid. They are also expensive to apply and to maintain, and usually give more trouble from leakage than the ordinary stay-bolt because the thread in the fire-box side is apt to be stripped in driving, inasmuch as there is less support for holding on, and also because of the tendency to drive them when in service without taking off the caps so as to enable the workman to hold on to the bolt.

Designers have been trying to reduce failures by increasing the length of the bolts and by decreasing their diameter. There are several reasons why a 7/8-inch bolt should last longer than

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* Abstract of a paper read at the Atlantic City meeting of the American Society for Testing Materials, June, 1904.

the 1-inch bolt, notwithstanding the fact that it has a smaller area. Stay-bolts are not loaded to a definite fiber stress (in which case the bolt of larger diameter would be the more serviceable), but they are deflected through a given angle, and the amount to which they are deflected cannot be altered by any increase in strength or in diameter. Inasmuch as the angle through which the axis of the bolt is bent is independent of the diameter of the bolt, the outer fiber of the smaller bolts and a crack will thus start sooner in the 1-inch bolt than in the ⅞-inch bolt. The time between the starting of the crack and the breakage of the bolt will be greater for bolts of large diameter than for bolts of small diameter. However, the bolt which remains in service the shortest time after a crack is started is the more desirable bolt, for after it is cracked the sooner it is removed the better.

A cable composed of a large number of strands will bend and twist many times without breaking, although the tensile strength is very much less than the strength of a solid bar of the same diameter. The nearer we approach to this condition in boiler design the less trouble we will have. Boilers have been built with bolts of ¾-inch diameter, but the bolts were spaced more closely than is usually the practice.

Small bolts also have an advantage in heading, for the hard hammering necessary to head a bolt of large diameter or of hard iron is liable to strip the thread of the bolt. Bolts of small diameter will not require heavy hammering and will therefore probably give less trouble from leakage than bolts of large diameter. Furthermore, the head of the bolt of small diameter would not be heated to as high a temperature as the bolt of large diameter, because it is more readily cooled by the water, and hence it would not expand as much. When the metal in the bolt expands it enlarges the hole in the sheet and puts a permanent set in the sheet and thus causes leakage. Another advantage in the use of bolts of small diameter is that they can be replaced many times without greatly increasing the diameter. The life of the fire-box would thus be increased. The future will probably see the more general use of ¾-inch bolts with closer spacing. The present practice of using a ⅞-inch bolt is a compromise between the most advanced and most conservative practice. An analysis of the stress in stay-bolts shows that the extent to which the bolt is strained increases in direct proportion to the diameter and decreases as the square

of the distance between the sheets. Assuming as a basis a stay-bolt one inch in diameter and deflected 0.03 inch and a distance between sheets of six inches, we find that the bolt has a fiber stress of 35,000 pounds per square inch. If the diameter is reduced to ¾ inch the stay-bolt is strained to but 26,250 pounds. By decreasing the distance between the sheets to five inches the bolts are strained to 50,400 pounds for the 1-inch bolt, and 37,700 pounds for the ¾-inch bolt. These results show very clearly the cause of stay-bolt breakage and what should be done in order to reduce the trouble to a minimum, namely, make the water space as wide as possible, and use a small bolt with a closer space if necessary.

A few railroads have recently specified very high tensile strength for stay-bolt iron. The question arises, is the tensile test a proper one upon which to rate stay-bolt iron? If a member is subjected to a direct tensional strain or a definite load a high tensile strength or elastic limit is desirable because it gives a high factor of safety. If, however, a member is subjected to a definite deflection then the stiffer the iron, the greater the load necessary to produce this deflection. In other words, a bolt of high tensile strength is subjected to a higher fiber stress than a soft bolt of low tensile strength. It is for this reason that steel gives excellent results in axles, etc., which are loaded to a definite fiber stress, but it will not answer for stay-bolts which are bent through a given angle. The manner in which the iron is piled and rolled plays a far more important part in the life of the bolt than the tensile strength, and after many experiments, those who have given the subject thought have decided upon a fagotted bar-piled iron. The central core is composed of a number of bars, approaching in appearance a bundle of wires. This core is enclosed by an outside sheath of metal with circular fibers. This insures a good thread and prevents the bolt being strained in a direction at right angles to the fibers. A soft ductile iron piled in this way undoubtedly gives better results than a hard iron of high tensile strength piled in the usual slab form. Stay-bolt iron made in this manner may be strained by bending in a direction at right angles to the fibers, and it would then have a very low life.

This subject has been thoroughly demonstrated by making vibratory tests of various makes of stay-bolt iron, and the results obtained in the vibratory machine have been confirmed by prac-

tice. The writer's attention has recently been directed to a marked difference in the life of stay-bolts on two groups of engines of precisely the same design and in operation on the same division. Upon investigation it was found that a very high-priced special brand of high tensile strength stay-bolt iron was used in the engines which gave trouble, while a good grade of well piled soft and ductile iron was used in the engines which were giving good service. The requirements specified by a number of roads in this country, follow:

Road	Tensile strength	Elongation, per cent
Atchison, Topeka & Santa Fé	48,000	28 in 8 in.
Baltimore & Ohio	48,000	25 in 8 in.
Chesapeake & Ohio	48,000	25 in 2 in.
Burlington & Missouri River	48,000	30 in 2 in.
Chicago, Burlington & Quincy	49,000	28 in 8 in.
Lehigh Valley	50,000	30 in 4 in.
Missouri Pacific	47,000	26 in 8 in.
Mexican Central	48,000	25 in 8 in.
New York Central	48,000	28 in 8 in.
Norfolk & Western	48,000	25 in 8 in.
Pennsylvania	48,000	25 in 8 in.
Philadelphia & Reading	46,000	45 in 2 in.
Seaboard Air Line	48,000	25 in 8 in.
Southern	52,000	28 in 8 in.
Harriman associated lines	52,000	28 in 8 in.

It is almost universal practice to specify 48,000 lbs. tensile strength, it being generally realized that an iron is thus secured which is strong, which will take a good head without hammering enough to strip the thread, and which will withstand the alternate bending.

A stay-bolt should be tested in a manner similar to which it is strained in service. Some years ago this matter was thoroughly agitated, and a large number of experiments were made with make-shift apparatus. The results varied widely largely because of the different methods of holding the bolt, and because the bolts were vibrated in one plane. Very good results would be obtained if the bolt were vibrated in a plane parallel to the direction of piling, while very poor results would follow if it were vibrated at right angles thereto. A machine has been designed to record the number of vibrations of a given amplitude which a test-bar

will withstand. It is especially adapted to the requirements of stay-bolt testing, and will hold stay-bolts from 3 in. to 8 in. long. The upper end is held rigidly while the lower end is given a circular vibratory motion, which can be adjusted from zero to a circle ⅜-in. in diameter.

NOTES FROM THE MICROCHEMICAL LABORATORY AT DELFT*

By H. BEHRENS
Professor at the Polytechnic School, Delft, Holland

I. Movements in Metals under Annealing

WHILE trying the experiments of Professor Spring on welding of metals at temperatures far below their melting points, I was struck with the dimmed appearance of polished zinc at temperatures above 200° C. The phenomenon, formerly ascribed by me to recrystallization,† presented itself on such a scale, that the corrugations could be perceived by the naked eye. The experiments were therefore continued, first on heavy sheet-zinc (12 mm. thick), later on cast pieces of tin and lead (about 15 mm. thick). The pieces of zinc were polished on two sides, one rolled surface and one surface made by the saw, they were then heated to 260°–266° C. in a drying oven and this heat was kept up for two hours.‡ After cooling the rolled surfaces were found full of wrinkles or creases, trending in the direction of flow, on the sawn surfaces small scales or leaflets were seen to protrude, pointing in the same direction. One of the pieces was polished anew and again heated to 260° C. By this treatment a relief of the same kind was produced, but not so strongly marked.

To exclude the influence of impurities and of mechanical deformation, experiments were made with cast samples of pure zinc. One sample was prepared by filing, grinding and polishing a stick of commercial pure zinc (10 mm. thick), another was made

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* Received October, 1903.

† "Das Gefüge der Metalle und Legierungen," S. 53, 56. See also *The Metallographist,* April, 1902, p. 100 (Ewing and Rosenhain).

‡ Later, heating on a strip of sheet iron, till a grain of tin, placed near the sample, will melt, was found sufficient, the heat being kept up for about five minutes.

of a block, prepared by melting a stick of the same metal in a porcelain crucible and cooling very slowly. After heating as mentioned above, the first sample was found uniformly dimpled, the second showed a more rugged appearance and coarser detail. Its surface was divided by innumerable cracks, some of which could be followed by the naked eye, into polygonal areas, among which the hexagon predominated. The cracks proved to be superficial, they were easily rubbed off on fine carborundum paper and would reappear when the sample was once more heated. However, the quality of the metal was found deeply injured. Two strips of thick plate-zinc were prepared of the same size, one of which was annealed. Then both were bent over a brass rod of five cm. diameter, till the polished surfaces began to look dimmed. After this treatment the annealed strip showed several cracks and a marked deficiency in elasticity. This experiment leads to the supposition of an internal strain and the microscopical evidence tends towards the same view. The edges of the polygons are nearly all protruding, besides, etching of an annealed sample will produce nearly the same pattern as heating and not a trace of liquation.

Metals, composed of isodiametric crystals, will return to their original form and bulk after annealing. If other metals are to show the same behavior, their crystalline constituents must be arranged on parallel lines, a condition not easily realized.* In the majority of cases heating will set up strains, by which the joints between the crystals will be widened permanently when the strains have accumulated in such a measure as to overcome the tenacity and ductility of the metal. Manifestly this will occur at first on the surface, and the accumulation of the strains will grow with the coarseness of structure.

In accordance with these views a polygonal relief was produced on tin† at a temperature of 150° C., but not so strongly

* Perhaps this reasoning may help to explain why the ductility of metals and alloys is increased by localized rapid cooling (mold with bottom of iron or cooled core) and by rolling.

† A similar pattern was produced by etching with hydrochloric acid. To account for this coincidence it should be borne in mind that etching on crystallized metals follows the same law as etching on crystals of rock salt or calcite. First the joints are attacked, then the central parts of the facets, at last the edges. Accordingly these will stand out in relief, keeping their polish.

marked as on zinc. Rills with upturned edges were easily obtained, but could never be made to develop into a network of well defined cracks. On common lead faint traces of a polygonal pattern have been seen; on copper, brass and iron nothing of this kind has been observed after annealing.

Widening of the joints must result in an increase of the bulk, and this may be controlled by comparing the density before and after annealing.

	Before Annealing	After Annealing
Rolled zinc	7.195	7.169
Cast zinc, cooled rapidly	7.172	7.086
Cast zinc, cooled slowly	7.170	7.045

The difference between the densities before and after annealing decreases with the size of the crystals in cast zinc. Further diminution takes place when the metal is rolled; this is probably due to increased parallelism of the crystalline constituents.

II. On Tinning and Soldering

When a piece of rolled copper is kept for about half an hour at a red heat in an alloy of one part of tin and 50 parts of lead, it becomes encased in bronze, and, after cooling, globules and imperfect crystals of bronze are found in the lead.* The casing is of an uniform light yellow color and the boundary line between copper and bronze is well defined and free from indentations, so this experiment does point rather to deposition from a supersaturated solution than to penetration (diffusion) of tin into solid copper. However, penetration will occur chiefly in the joints between the crystals, and these are nearly obliterated in rolled copper. For this reason I resolved to try tinning cast copper. Dissolving action was excluded as far as possible by working with a very thin layer of tin and at temperatures below a red heat.

First the polished copper was tinned at 250° C., wiped while hot, cooled speedily and polished till a reddish tint began to show itself. Under the microscope no trace of yellow bronze could be detected. Cautious etching with aqua regia revealed a faint white network, corresponding with the joints, that were laid bare by

* "Das mikrosk. Gefüge der Met. u. Legier.," S. 35.

more severe etching. So, liquid tin had acted as a mild etching solvent.

Then the copper was tinned once more and superheated, till the Bunsen flame took a greenish tint. The metal became dry, as if it were powdered with chalk, afterwards the color turned to light brown. The coating now proved harder than tin and would not take a perfect polish. Under a low power it had the appearance of a felt, under a medium power (150) this was resolved into needles of a faint yellow color, like the needles of the compound $CuSn_2$ found by H. Baucke in bronzes with more than 50 per cent tin. Under this felted layer by means of continued polishing and cautious etching a whitish network was brought to light, of the same kind as that mentioned above.

Yellow bronze was obtained by tinning the copper a third time and heating it for five minutes to a clear red heat. A very hard layer of white bronze was formed; under this was found a thin coating of yellow bronze, penetrating a little way into the copper as a yellow network.

From these experiments may be deduced that the solvent action of tin increases with the temperature, that the diffusion of liquid tin into solid copper is subordinate to its solvent action and that the nature of the deposited tin-copper alloy is determined by the temperature at which the solution of copper in tin was saturated. The fastening of tin on copper under ordinary circumstances of tinning must be ascribed chiefly to adhesion, like that of rosin on glass.

These conclusions were confirmed by observations on tinned and galvanized sheet iron. A slight etching of tinned iron gave a solution of pure tin, later (third etching) also iron was dissolved and finally on gray patches of metallic iron tiny needles of an alloy were found. Galvanized iron is manufactured at a much higher temperature and left immersed a much longer time. The coating is thereby strongly charged with iron and this is readily detected by heating with caustic ley. The sample is immediately blackened and the black powder is found to consist of black oxide of iron. The penetration of zinc into the iron is found insignificant, here, even as with tinned iron and tinned copper, adhesion does play the principal part. Even in brazing with hard solders penetration of the solder into the solid metal is of small importance. It was tried with cast iron and brass, with cast iron

and copper, with copper and brass, with copper and silver, invariably with the same result, viz., a sharp boundary line, showing here and there under high powers uncertain traces of ramification.

III. Etching by Means of Electricity

Etching on metals by means of the electric current. By A. H. Sirks. Abstracted from "Kon. Akad. v. Wetensch," Amsterdam, in "Science Abstracts," January 26, 1903, and in *Metallographist,* July, 1903, page 264.

As the experiments of Mr. Sirks have been made in the mineralogical laboratory, it was found necessary to give his method a trial in the micro-chemical laboratory of the polytechnic school. Good results were obtained on Babbitt metal, on brass, on white bronze and on some varieties of cast iron. On yellow bronze, on rolled brass and steel the results were poor and on lead and its alloys no etchings could be obtained. A current of four volts is not needed, provided, that a bath of sufficient concentration is used. When the cathode is immersed in a saturated solution of copper sulfate and the anode in a saturated solution of an alkali salt, acids may be dispensed with and the current of one Daniell element will be found amply sufficient. Copper alloys may be etched in the solution of copper sulfate; for other metals a porous beaker is put in, filled with a saturated solution of common salt for iron, tin and Babbitt metal, of saltpeter for lead and its alloys. On lead and its alloys etching by means of electricity showed a decided superiority, in all other cases etching with acids or ammonia is to be preferred, as it may be done in a quarter of the time and with less than half the apparatus required for etching by means of the current. As to detail, electrical etching on copper alloys was found inferior to etching with ammonia, and the appearance of brass and bronze, etched by means of the current, so ungainly, that brushing with ammonia must be applied, to give the surface a little metallic luster. Generally speaking, etching by means of the current may be carried to a greater depth, than etching with acids. The reason is to be sought in a circumstance, not mentioned by Mr. Sirks, viz., that the current will give a maximum of chemical effect in the vicinity of the surface that is attacked, while reagents applied for chemical etching are used up and the hollows of the etching filled with a dense solution of

the metal. That polishing may be dispensed with for etching cast metal of coarse structure is universally known. For chilled castings and for rolled metal great care in polishing will always be found necessary.

Mr. Sirks would have us believe that crystalline particles might be separated from alloys by means of electrolytic treatment. I have tried this on castings of brass and of aluminium-copper alloy (10 per cent Al), with the same negative result as when working with nitric acid. Babbitt metal and white bronze, the alloys on which Mr. Sirks has experimented, have been subjected to chemical separation by Mr. H. Baucke, Amsterdam, about six years ago ("Notul. v. h. Kon. Instit. v. Ingen.," September 6, 1897).

IDEAL STEEL *

THE investigations, discoveries, and theories of the last few years — we had almost said the last few months — have had the effect of liberating speculation. We may contemplate in imagination, without foolishness, the possession of powers and materials which not long ago would have been regarded as existing only in wild dreams. The time has not long passed when it was held that the limit of knowledge concerning steel had been nearly reached. A very few men of unusual ability hold, it is true, that finality can never be attained in science; and seeing how important and how little understood a part was played by minute quantities of carbon, manganese, sulphur, phosphorus, and silicon when alloyed with pure ferrite, they pushed inquiry without despair, to ascertain whether other materials might not also produce remarkable changes in the characteristics of a metal which plays so important a part in the modern world. Those who have followed the report of the Alloys Committee, or watched the progress of high-speed tool steel, will, without exception, we think, admit that further progress is not only possible but probable, and will agree with us that it is not easy to construct in theory a steel which it is impossible to make in practice. We may anticipate the commercial production of a material of construction almost as remarkable as we please without fear of incurring ridi-

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* "The Engineer," April 15, 1904.

cule. That this is the case is directly the result of the enormous advance which has taken place in steel lore; in our knowledge of what it is, and how it is affected by temperature changes, and the addition of various elements, or so-called elements.

Let us then suppose that there is in existence an ideal steel, and consider what benefits it can confer. The steel shall have a breaking strength of 55 tons to the square inch; an elongation on ten inches of 40 per cent. The elastic limit shall be 30 tons; and a ⅜-in. thick test strip shall bend flat on itself, cold, without a crack. It will harden very slightly when cooled, and its price shall not be too great to put it out of the market. Steels of even a higher tensile strength have been made, of course; but we think that the combination of qualities which we have specified above is so far unknown in the steel markets of the world. At first, engineers would be slow to believe that judged by all existing standards, the new steel would be practically twice as strong as any other constructive steel in the market. If six tons per square inch is a safe load for a 30-ton steel, then 10.5 tons, or a little over, would be safe for a 55-ton steel. It is true that in bridge work, and, indeed, in all work, the elongation percentage is of use only as a test of merit in resisting shock, vibration, and repetition of stresses. But it is obvious that if 20 per cent is held to be very satisfactory, double that must be still better, seeing that it is not coupled with a plasticity which reduces the elastic limit. It is, we think, impossible to regard such a steel as anything but a material nearly twice as good as the best steel now available. With this metal the dead weight of a bridge might be reduced to about 65 per cent of the least now possible, and in consequence spans might be adopted which would have appeared even on paper preposterous a few years ago. We need scarcely stop to point out at any length that, although the price of the new steel were nearly double that of existing steel, it would be much more than worth the money. The actual weight to be used would be reduced; but beyond this the cost of construction, false works, carriage, etc., would be diminished to a most notable extent. There is a multitude of situations abroad in which such a steel would be cheap at three times existing rates.

For marine boiler work our ideal steel would open up a new era. Instead of steel plates 1¼ in. thick, something under ¾ in. would suffice. The advantage secured would not be confined to

the saving in dead weight. The cost of construction would be reduced, caulking and riveting would be facilitated to a remarkable degree; much lighter, smaller, and cheaper plant would suffice for manufacture. On the other hand, our ideal steel possesses all the characteristics required in a material for the tubes of water-tube boilers. So far as can be presupposed, it would answer perfectly as a substitute for copper in the fire-boxes of locomotives. There is, at all events, no ostensible reason why a material so strong and ductile should crack. It is not, we think, necessary to pursue this line of argument further. The benefits to be conferred on the world by our ideal steel are sufficiently obvious.

Will the metallurgical chemist ever give us this ideal steel? Will it be the result of discovery, or of invention, or of both? We think it may be said with some certainty that when it comes it will not be a nickel steel, nor will its excellence be due to any constituent now used outside the region of experiment as an alloy. It will be the result of the most recent investigations in the effect of alloying materials hitherto little known — possibly not known at all outside a limited circle — as likely to affect the nature of steel. Will our ideal steel ever exist? Does it exist at this moment?

LARGE BLAST-FURNACES *

RECENT discussions on iron blast-furnace practice, together with same results of experience, indicate a tendency among engineers to the belief that expansion in size has been rather overdone. Some do not hesitate to say that the stacks of 500-ton daily capacity, which have been built during the past two or three years, are not quite fulfilling expectations. Others, there is reason to believe, hold much the same opinion, though they may not be quite ready to express it publicly. We do not mean to say that opinion is unanimous, for there are many who still believe in the big producers. There is no doubt that they have been successful, so far as quantity is concerned. Economy is another matter, and upon that point the question generally turns.

The arguments against the large stacks are that they consume more fuel per ton of iron made than the smaller furnaces;

* "The Engineering and Mining Journal," April 21, 1904.

that only the best quality of coke can stand up under the heavy burdens; that they are more liable to slips and explosions; and that the quality of iron made is less uniform.

To take these charges in reversed order, the last one may be dismissed at once, since there is practically no evidence to support it; and practically, also, no reason for it, if we except irregular charging and inefficient management, which are as likely to affect small furnaces as big ones. The third charge seems, from all the evidence that can be collected, to have some foundation. In the nature of the case it looks probable; though it may be due in part to the fact that the very large furnaces have been experiments, and there are questions of proportion, slope of walls and the like, upon which the best authorities differ, and which can be decided only by experience. The point upon which experts seem most nearly united is that there has been a tendency to excessive height of stack and that, in all probability, a furnace 80 feet, or 85 feet in height would work more smoothly, and with less tendency to accident, than one 100 feet high. This also affects the coke question to some extent, since a reduction in height means a reduction in burden.

The extended use of fine Mesabi ores also finds an important place here. Only a short time ago, when most of the big furnaces were designed, Mesabi ores made up from 25 to 50 per cent of the charge. The proportion of fine ores has gradually been increased until some very large stacks are now running upon such ores exclusively. As the Mesabi range is now that part of the Lake Superior region which is increasing its output, it is evident that furnaces must continue to use these ores in large proportion, if not entirely; and they must be designed and built accordingly.

The comparative consumption of fuel per ton cannot be determined until we are in possession of exact data relating to the performance of some of the large furnaces; and such figures have not been made public. That there is a saving in first cost, and therefore in interest charges, and also some economy in labor, is generally admitted. Whether these points will offset the increase in coke consumption can only be decided, as we have said above, when complete data are accessible.

At present no very large furnaces are under construction, or planned. This is due, however, chiefly to the lull in the iron trade, which does not encourage new undertakings. Whether any more

500-ton furnaces will be built in the near future, is a question involved in some doubt. It is quite possible that straining after large quantities in production may have somewhat passed the limit, and that when new building starts up again we may see some reaction in favor of furnaces of more moderate size, especially if Mesabi ores retain their present prominence in the supply, as they are pretty sure to do.

THE DECAY OF METALS *

IN many constructions the choice of some of the materials used is determined more by their durability under conditions of working than by their strength or other qualities, a more expensive and weaker material being chosen in preference to a cheaper and stronger, on account of its resisting corrosion better than the latter. Examples of this are afforded by the use of copper, brass, gun metal, or some of the special bronzes, in places where, except for their want of durability, the stronger and cheaper iron or steel would be preferable. The ordinary oxidation of iron and steel will not be dealt with, but a deterioration which sometimes occurs in cast iron and other metals, from causes which are to some extent obscure, will be considered. This deterioration will be generally referred to as decay.

As indicating the important bearing of the subject upon practical work, the following examples of deterioration may be mentioned:

1. The pitting of the tubes of marine surface condensers, which is a source of frequent trouble to marine engineers.

2. The decay of brass or yellow metal bolts in composite vessels, and in the underwater fittings of iron and steel ships.

3. The decay of the brazing metal in copper steam pipes.

4. The deterioration, as distinguished from oxidation, of cast iron used for parts of marine engines, and also for other appliances which are in frequent or continuous contact with sea water.

5. The decay of some propellers made of certain bronzes when fitted to copper bottomed vessels.

The most serious feature of such deterioration which has been observed is that the action to which it is desired to call

* "The Iron Age," April 7, 1904.

attention seems to be erratic; considerable trouble arises in certain cases, while in others, under similar conditions, no such results occur. Further, the action often proceeds to a considerable extent before ordinary examination will reveal it, because the metals when deteriorated preserve their original external appearance.

Summarizing the whole subject, it would appear that:

1. Decay is more frequent in metals which have a duplex or more complex structure than in those which are comparatively homogeneous.

2. Decay is due to a slower or less energetic action than that causing corrosion; moreover, it requires an action which removes part only of the constituents of the metal, whereas corrosion removes all the metal attacked.

3. Both decay and corrosion may result from chemical action alone, or from chemical and electrolytic action combined.

4. Pitting, or intense local corrosion, is probably often due to local segregation of impurities in the metal; but it may also in some places be due to favorable conditions furnished by local irregularities in the distribution of galvanic currents.

5. For brass exposed to sea water, tin is distinctly preservative, while lead and iron are both injurious rendering the alloy more readily corrodible. The percentage of the two latter metals should therefore be kept as low as possible in all brass intended for purposes where contact with sea water is inevitable.

6. With a view to obtain a minimum of corrosion, the internal surfaces of condenser tubes should be as smooth and uniform as possible, and in order to insure this condition the cast pipe from which they are drawn should be smoothly bored inside, either before the drawing is commenced, or in an early stage of the process, as is done in the manufacture of brass boiler tubes.

7. The experiments with an applied electric current show that electrolytic action alone, even where exceedingly minute currents are employed, may result in severe corrosion or decay. Every effort, therefore, should be made to prevent such action by careful insulation of all electric cables. Where galvanic action is inevitable, through the proximity of different metals exposed to the same electrolyte, the currents resulting should be neutralized by the application of zinc plates in the circuit so arranged that they will be negative to both of the other metals.

THE HEAT TREATMENT OF STEEL*

Sixth Report of the Alloys Research Committee upon the Behavior of Alloys of Carbon and Iron

INSTITUTION OF MECHANICAL ENGINEERS

AMONG the valuable investigations conducted by the Institution of Mechanical Engineers the successive reports upon alloys have held a high place, and the appearance of the sixth, and last of the present series demands careful attention and review. In some sense these reports form a memorial to the late Sir W. C. Roberts-Austen, since the important share which he took in the investigations upon which they are based has been well known, and the fact that the present report is the only posthumous work of his rendered its appearance an occasion for some worthy tributes to his memory. The report, although blocked out by Sir William Roberts-Austen, is practically the work of Professor William Gowland, assisted by Mr. Merrett, Mr. Harbord, and others, to whom full credit should be given.

The sixth report practically forms a supplement to the fifth report, continuing the subject of steel, considered as an alloy of iron and carbon and of other minor constituents, and is devoted entirely to the effects of heat treatment upon test specimens of different chemical compositions. The tests were made upon steel of eight different compositions, each variety being subjected to twenty different kinds of heat treatment, thus giving 160 variations, the effects being examined by mechanical and metallographical examination, this plan being devised to enable comparative data to be secured for future study.

In this introduction Sir W. Roberts-Austen emphasizes the vital importance of the consideration of the phenomenon of allotropy in connection with the study of the properties of steel. The allotropic changes in the iron itself are all important factors in determining the relations between iron and carbon which are involved in the characteristic capacity of steel for being hardened and tempered. The question of annealing is included in the work discussed in the report, the definition of annealing adopted being that of Sauveur as the operation of rendering the quenched metal "as soft, tough, and ductile as possible, by decreasing the elastic limit and tensile strength only by such abnormal increments as

*"The Engineering Magazine," March, 1904.

were acquired by hardening and cold working." The annealing of the test specimens under consideration was effected by maintaining the steel at a temperature ranging between 625° C. and 1,100° C., followed by a more or less prolonged cooling.

In connection with the investigations upon annealing a portion of the report is devoted to a study of the effects of "soaking," or the exposure to heat for a prolonged period. This has been effected by examining the properties of specimens which have been heated to definite temperatures for twelve hours, with the result of showing very definitely the changes which this operation is capable of effecting.

The third portion of the report is devoted to a discussion of experiments upon hardening, this effect being produced by causing a portion of iron carbide to be dissolved in the iron and a reversion to the soft condition being prevented by the rapid abstraction of heat.

The report is therefore divided into three parts, treating successively of annealing, soaking, and hardening, each of these being discussed with the aid of tables diagrams and microphotographs. Its voluminous character prevents anything but a general review of the results here, while reference to the original will enable detailed information to be gathered from the tables and other records. The report is a noteworthy example of the extent to which the new science of metallography is coming into practical service, and the microphotographs are very fine examples of the work of the microscope and the camera.

One of the most important results of the annealing experiments is the confirmation which they give of the effect of moderate temperatures, a heat of 620° C. having a perceptible effect in increasing the elongation. The continuation of the annealing experiments shows that a temperature of about 900° C. gives the best results, the bars heated to this temperature for half an hour showing practically a complete solution of the various constituents, permitting rearrangements to take place according to the rate of cooling. Under these conditions the maximum strength is obtained, as well as a material increase in elongation under test, while if this temperature is greatly exceeded the material is liable to become burnt.

Passing to the soaking experiments, in which a period of twelve hours instead of half an hour was given to the heating of

the specimens, it appears that the increase in the duration of application of heat has a marked influence upon the material. The effect upon bars soaked at a temperature of 620° C. was to reduce both the breaking strength and the elastic limit, but to increase the elongation very materially over that of bars heated only half an hour. At the higher temperatures no material difference was shown for the soaked bars over the annealed specimens, except for the bars containing 1.3 per cent of carbon, which, when soaked for twelve hours, showed a greatly increased degree of elongation.

The most important conclusion drawn from the results of the soaking experiments is the possible availability of the process for the production of metal suitable for the construction of gun tubes.

The present method of producing large ingots of gun steel is by quenching in oil and subsequent annealing, but with pieces of large size it is difficult to secure uniformity by this process. By an examination of the experiments, however, it appears that the necessary mechanical properties for the construction of ordnance have been obtained in soaked and slowly cooled low carbon "special" steels. It also appears possible to use an ordinary "soaked" carbon steel for this purpose, so that the researches of the committee in this direction may prove of great value in connection with ordnance construction.

The experiments upon hardening contain results obtained by heating the specimens to temperatures from 720° C. to 1,000° C. and quenching them in various cooling liquids. Since this process is one frequently used in the arts, and one concerning which many discussions have been held, and numerous nostrums advocated, some of the remarks about it are of interest. Within certain limits, the more rapidly the heat is abstracted the more effective will be the hardening. The bath must be large enough to have its temperature but slightly affected during the quenching of the metal, otherwise the hardening will not be uniform. In the tests discussed in the report water was used, and also oil, the results being very fully tabulated and illustrated. The relation of the hardening temperature to the carbon content and to the general composition is clearly shown, and the results should be of material value in connection with practical operations of this sort.

The whole report is a most valuable contribution to the applied science of engineering, and the Institution is to be congratulated upon the success of the work of the committee which it has appointed and maintained. It is just such work as this which removes "practice" from the domain of empiricism and relieves theory from the imputation of impracticability. When all the fundamental operations and methods of engineering are subjected to such judicial investigation and study, the opportunities for quackery in applied science will be vastly diminished, and the progress of civilization correspondingly aided.

THE HEAT TREATMENT OF STEEL*

THE discussion of the sixth report of the Alloys Research Committee was concluded at the Institution of Mechanical Engineers on Friday evening last. There were no new speakers. Mr. Merrett replied to some of the questions that had been raised on the two previous evenings; and Professor Gowland, in a written communication, since he was unfortunately prevented from attending by illness, replied to others.

We propose now to review the discussion as a whole. It commenced after the reading of the report on January 15th, was adjourned, and continued at a special meeting on January 29th, and was concluded, as already stated, on Friday last. No less than fourteen members took part in it, and for the greater part they were the accepted authorities on metallurgical questions.

The discussion opened with a short introduction by the President, Mr. Hartley Wicksteed. He outlined the history of the report and the work of the Committee, and expressed on behalf of the meeting the thanks that were due to the late Sir William Roberts-Austen, and to his successor in the Chair of the School of Mines, Professor William Gowland, who were responsible for the report itself, and to Mr. W. H. Merrett, who had done most of the practical work in connection with it, and to Mr. Harbord, Mr. Smith, and Mr. Reilly, who had assisted in various ways.

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* "The Engineer," February 26, 1904.

The first speaker in the discussion was Mr. Le Chatelier. He touched upon three points. The first was the value of the Research Committee; the second the desirability of using notched bar tests; the third the lack of uniformity in the definition of certain substances. Thus what one metallurgist called martensite, another called troostite, and a third sorbite. There was much work to be done before the characteristic properties of such constituents of steel could be accurately defined. The speaker enforced his remarks on the value of notched bar tests by a telling table which he wrote upon the blackboard. It showed the results of tests made on a bar of mild steel with a breaking stress of 38 kilograms per square millimeter, and 34 per cent elongation. It was divided into three parts, and from each a test piece was cut, with the object of judging the homogeneity of the bar. The three pieces were heated to 950° C. and tempered at 600. One was used as a standard, whilst the others were raised to a white heat, one for 15, the other for 30 minutes. Three tests were made: (1) Ordinary tensile; (2) notched bar; (3) Wohler test, i.e., rotating the bar under a bending load. The table was as follows:

1. Steel quenched at 950, tempered at 600.
2. The same, and annealed for quarter-hour at 1100.
3. The same, and annealed for half-hour at 1100.

Specimen	Tensile test		Notch test Kilogram-meters to break	Wohler test Revolutions to break
	Breaking Stress	Elongation		
1	38.9	35	32	175
2	38.6	29	20	135
3	38.6	29	1	70

This table showed that the third bar differed far more markedly from the first bar than the tensile test would lead one to believe.

Mr. Harbord followed Mr. Le Chatelier, and the point of importance in his speech turned upon the smallness of the test specimens. The experiments of the report were, he explained, to be regarded only as pioneer experiments, and it had been Sir William Roberts-Austen's intention to carry on the research with much larger pieces. He adduced, however, a number of figures from various authorities — Brinell, Arnold, etc. — which sup-

ported the figures given in the report; but, on the other hand, he had found that the results obtained by Mr. Campion, and given to the Iron and Steel Institute last year, on large test pieces were at variance with the figures given in Table V of the present report. Campion was of the opinion that heating above 850° was more likely to cause brittleness in steel than to improve its mechanical properties. Mr. Harbord thought that where the results of tests on large and small specimens were in conflict, those from the larger pieces should be selected.

Professor Turner and Dr. Glazebrook offered tributes to the memory of the late Sir William Roberts-Austen and to the great work he had done for metallurgy, and Dr. Glazebrook expressed a hope that the National Physical Laboratory might be allowed to assist in the prosecution of further tests under the direction of the Alloys Research Committee.

Mr. Stromeyer wanted more tests and longer test pieces. He especially recommended the use of torsion tests, which gave useful data about shearing, and which were particularly valuable to gun makers, since the metal was subjected to something resembling the compound stresses set up in ordnance. But, more than any particular method of testing, he thought it important that experiments should be carried out on mild steel, the metal most generally employed by engineers, of whom only a limited number had to deal with high carbon steels. He instanced two cases where impurities had affected mild steel in a remarkable manner. One of these was a plate from which test pieces were satisfactory, but which cracked in the rolls when being bent to quite a large radius; the other was the case of a steel which would weld well, but cracked immediately afterwards. Such examples as these, he thought, showed the necessity of investigation into the effect of impurities on mild steels.

Dr. Kirk Rose, of the Royal Mint, dwelt upon several of the theoretical as distinguished from the utilitarian parts of the report. He discussed some of the curves which have been designed by metallurgists to represent the changes in metal, and asked if there had been sufficient experimental proof to verify them. There were many figures in the paper that bore upon this point, but Professor Gowland had a great deal more information on the whole subject, and he appealed to him to give them a summary of the conclusions that might be drawn from the report. Coming

to more essentially practical questions, he said he thought it was not sufficiently generally recognized that the composition of the steel determined the temperature at which it ought to be quenched, and that for complete hardening it should be homogeneous at the moment of quenching.

This concluded the discussion on the first evening. On its resumption Mr. Stead was the first speaker, and he commenced by outlining the history of the steels which had been used by the Committee. No. 1 sample was a basic steel made by the Saniter process; it contained more arsenic than Swedish steel. No. 2 was a Swedish Bessemer steel. The others were all crucible steels. All the steels were rolled and cold reeled, which gave them a good appearance, but apparently did not improve their mechanical properties. The speaker then went on to give an interesting explanation of the changes that take place in steel bars. Such a series of changes is readily obtained by heating one end of a bar in a furnace whilst the remainder is exposed in the air. The bar is then at different temperatures along its whole length, and if cooled suddenly in water the condition of the steel at that instant is retained, and by cutting sections may be examined at leisure. Mr. Stead gave an interesting diagram, which explained the nature of the changes which took place. Turning to the report itself, the speaker spoke of the desirability of checking the figures given in Table IX, which appeared to him to be extraordinarily high, and corrected the wrong impression given by a passage in the report that he favored soaking at 900° C., a practice to which he was, as a matter of fact, strongly opposed. He pointed out that the statement given in a previous report that austenite had no cutting value had been disproved, and it was now believed that the value of high-speed steels was largely due to its presence.

Professor Arnold followed, and dealt trenchantly with the report, attacking the allotropic theory with characteristic energy. It is unnecessary, we think, to follow him through that part of his speech. But on the more practical part of the paper he had not many better words to give. He thought that the steels employed for the test were absolutely abnormal, and should never have been used, and he did not agree with Mr. Stead that their badness was due to cold-reeling. He complained, too, of the use of the term breaking strain on all the diagrams, and suggested that maximum stress would be a better expression. He spoke of the antiquity

of the plan of heating brittle steel to 900° C., and allowing it to cool, and said that in Sheffield it was not known as restoring, but as "faking" steel. Through the kindness of Mr. Milton, he was able to tell the meeting of a one-inch boiler-plate which, though its chemical analysis was correct, and though it had stood its mechanical tests properly, split from end to end like glass under the final hydraulic test. It was only one case among many that had come to his knowledge, and he was convinced that once brittleness had developed, heat treatment or anything else only aggravated the trouble. Steel that had once become brittle could not be cured, it was only fit for the scrap heap.

Mr. Hadfield also dealt, in large part, with the allotropic theory. He thought that a truce might now be called, and a common ground found for discussion, and that the carbonists and allotropists might meet and arrive at a mutual understanding. He gave some very interesting figures bearing on the effect of low temperature on nearly pure iron. A specimen of such iron tested under ordinary conditions showed a tensile strength of about 21 tons, with an elongation of 25 per cent; the same iron tested at a temperature of — 180° C. ran up to 54 tons tensile, and was without elongation; but this specimen after its return to normal temperature bent double.

Professor Unwin thought that the anomalies in the figures of the report were due to the smallness of the test bars. In such small pieces very slight differences produce very marked effects, and he thought it was desirable that questionable figures should be checked by tests on larger specimens. He noticed the exceptional ratio of elastic limit to breaking stress in some specimens, and thought it might be due to error of observation, since it was by no means easy to determine the yield point in a gauge length of two inches. He touched, too, upon the difficulty of avoiding bending stresses even with spherical seatings, and commented on the great effect such bending would have on hard steel specimens. He thought that in the future notched bar tests might be largely used, but they needed to be standardized before they could be generally accepted and understood. He mentioned the curious fact that if ordinary test bars are notched and tested in the tensile machine, they give results analogous to the true notch bar test, thus proving that the effect is due to the notching and not to impact.

Dr. Carpenter, referring to some of the micro-photographs, made some suggestions as to their interpretation. His remarks were mainly of academic value.

He was followed by Sir William White, who held out an olive branch to Professor Arnold. He spoke of the value of the report and of its great suggestiveness, which would encourage others to follow up similar inquiries, and whilst giving full praise to Professor Arnold for the excellent and admirable work he had done, he felt sure that the Alloys Research Committee had stimulated him in the prosecution of his investigations. Referring to one or two of the criticisms that had been made, Sir William impressed upon the meeting the fact that the expressions of opinion in the report were the late Sir William Roberts-Austen's; they did not emanate from the Committee as a whole. On the question of duplicate tests, he said he thought the Institution had done its work, and that the manufacturers now should take up for themselves further investigations. It was not a wholesome state of affairs that all research work should be conducted in laboratories. The manufacturer was the right person to make investigations bearing on his own business, and they should be made on a large scale in industrial establishments. The facts that had been proved by the Committee were, he thought, as follows: First, it had been shown that traces of elements profoundly affect the properties of steel; that heat treatment has also marked effects; and, thirdly, that the influence of heat treatment might be expected to take the place of mechanical work.

In conclusion, he informed the meeting that Dr. Glazebrook's offer to carry on the work at the National Physical Laboratory had been cordially accepted, and that Captain Sankey had offered to make notch tests of some specimens still in possession of the Committee.

Mr. Belcher, of Coventry, having spoken of the uncertainty of notch tests, and Mr. Belshaw, of Manchester, of the marked effect that differences as low as 1° C. had on hardening, and Mr. Harbord having made a few comments on Professor Arnold's observation about the quality of the steel, the second day of the discussion was closed.

On the third evening, as there were no additional speakers, the replies were taken. Mr. Merrett spoke first. Speaking of notched bar and torsion tests, he pointed out that at the present

time commercial specifications avoid such tests, but he thought that had Sir William Roberts-Austen lived, the former, at any rate, would have been made. Replying to Mr. Belshaw, he thought it must be a very special class of steel that was affected by such small difference as 1° C.

In the absence of Professor Gowland the Secretary read his reply. He emphasized what Mr. Harbord had said about the pioneer nature of the tests. They had never been intended to be exhaustive, but were regarded as preparatory to investigations on a commercial scale. They had been given because it was desirable to prevent a number of different experimenters going over similar ground. Speaking of mint dies, he remarked that it was impossible to determine the hardness after quenching, since nothing could be known of the interior of the steel. The only test was the number of coins that could be struck. A higher temperature than 750° C. was needed, otherwise the dies sunk in the middle. But the number was further influenced by the nature of the stamp used for making the die. If it were flat the full number could be struck, but if it were curved fewer and fewer could be made as the curvature increased. He supported what Sir William White had said about the desirability of manufacturers conducting tests on larger specimens.

Mr. Wicksteed then wound up the debate. He told the meeting that it had been decided to carry the work on, and that money had been voted by the council for that purpose; he invited communications from commercial users of steel on the directions in which experiments should be made; and, finally, he added that Professor Arnold had expressed his desire to coöperate with the committee in the work.

THE ESTIMATION OF CARBON IN IRON-CARBON ALLOYS *

By H. C. H. CARPENTER

IN the following article an attempt will be made to gauge the limits of accuracy of the most trustworthy methods of estimating the various forms of carbon in the commercial alloys of iron and carbon, viz., steel, pig iron, etc. For details of the methods, readers are referred to Brearley and Ibbotson's "The Analysis of Steel-Works Materials," and Blair's "The Chemical Analysis of Iron."

In addition to the errors of the particular chemical method employed, there is the well-known difficulty of obtaining a thoroughly representative sample of the material to be analyzed. The reason for this is, that the alloys of iron and carbon are seldom homogeneous or uniform mixtures. A steel containing anything up to about 0.9 per cent of carbon, hardened from a sufficiently high temperature (viz. 900° C.) has a homogeneous physical structure. An unhardened steel containing about 0.9 per cent carbon consists of a uniform mixture of iron and carbide of iron in fine plates called pearlite. But these are exceptional instances. Rail steel, with about 0.4 per cent carbon, consists of pearlite in an excess of ferrite (iron). Gray pig consists of a mixture of pearlite (soft) with graphite (soft), and an excess of carbide of iron. The white irons contain pearlite, with a large excess of iron carbide.

There is less difficulty in obtaining an average sample of the low-carbon unhardened steels. In this case the material is soft and the drill bores out long shavings. In the case of high carbon iron, a powder consisting of fine and coarse particles results; the most accurate results are obtained by sieving the powder, weighing the fine and coarse particles, and thus determining their relative proportion, and estimating the carbon in each. Another good plan is to grind the powder in a porcelain mortar until it passes through a fine mesh.

There can be little doubt, however, that a method of sampling, in which the error is less than that of the chemical method of determining the total carbon, has still to be found.

The Estimation of Total Carbon. — The method which is

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* "Technics," April, 1904.

generally accepted as being the most accurate involves the solution of the material in potassium-copper chloride liquor, and the combustion of the carbonaceous residue in a stream of oxygen, the carbon being weighed as carbon dioxide. According to the experiments of the American members of the International Steel Standards Committee, accurate results are obtained only if the potassium-copper chloride is acidified with hydrochloric acid at the outset. On the other hand, some hold that this causes a loss of carbon in the form of hydrocarbons, and that it is not safe to acidify the liquor until the steel or iron is entirely dissolved, the purpose of the acid being to dissolve precipitated copper.

In either case remarkably concordant results can be obtained by this method. The following figures have come under the writer's experience, using Blair's method:

1. 0.120	0.169	0.798	0.805	per cent
2. 0.120	0.169	0.797	0.803	per cent

It is probably not overstating the case, to say that this method, *per se,* is capable of giving an accuracy of one part in a thousand. The errors of sampling are, however, seen in the fact that, taking the whole range of iron-carbon alloys, duplicate analyses show, on an average, differences of about two per cent on the absolute amount. There is an uncertainty of at least one unit in the second place of decimals in most cases; and it is frequently more.

The method of direct combustion in the wet way (*vide* Brearley and Ibbotson, pages 11-13) is probably capable of about the same accuracy.

The Varieties of Carbon. — Ledebur, in 1893 ("Journal of the Iron and Steel Institute," Vol. II, page 53), distinguished four modifications of carbon: (1) graphite carbon; (2) temper carbon; (3) carbide carbon; (4) hardening carbon; and although Nos. 1 and 2 have certain properties in common, they cannot be regarded as identical.

Graphite carbon is a constituent of gray pig iron. It occurs in the well-known tabular hexagonal scales and is formed by the crystallization of carbon from *fluid* high carbon irons, when the rate of cooling is sufficiently slow.

Temper carbon is produced when white pig iron is annealed at about 1,000° C., owing to the decomposition of iron carbide at this temperature. In contradistinction to graphite carbon, it appears to be completely amorphous. It is the form in which carbon separates from a *solid* high carbon iron.

At the present time there is no method of estimating graphite carbon in the presence of temper carbon, and *vice versa,* owing to the great similarity of their chemical properties. If, therefore, they occur together, they have to be estimated together. The method which gives the most uniform, and probably the most accurate results, consists in dissolving the material in nitric acid (specific gravity 1.2), thus removing hardening carbon and carbide carbon, and following the directions given by Blair (page 167).

The accuracy of this method is probably not far short of, if indeed it is at all inferior to, that described for total carbon. The chief uncertainty is as to how far these two forms of carbon are insoluble in nitric acid. According to Jüptner von Jonstorff "Journal of the Iron and Steel Institute," 1897, No. 1, page 249), graphitic and temper carbon are oxidized" slowly, but completely," by boiling nitric acid. Further, the uncertainty, due to difficulties of sampling, is more pronounced in graphite determinations than in the case of the other forms of carbon.

The chief chemical difference between graphite and temper carbon is that when the high carbon iron is treated in such a way as to produce malleable castings (e.g., by heating it with hematite), the temper carbon is oxidized, while the graphite remains unaltered or very nearly so. Similarly if the iron is heated to redness in hydrogen, the temper carbon is more rapidly removed, in the form of a hydrocarbon, than the graphite carbon. But in neither of these cases is the distinction sufficiently sharp to admit of an accurate means of separation. And it must be admitted that, in the present state of our knowledge, there seems no prospect of obtaining a separation by chemical means.

Carbide Carbon. — This form of carbon is found in annealed steels and pig irons. In alloys wherein the carbon does not exceed 0.9 per cent, it occurs in thin plates, while with higher percentages it is found in addition as comparatively large and irregularly shaped pieces. The carbide was isolated by Abel, and has recently been thoroughly studied by Mylius, Förster and

Schoene.* The analytical numbers correspond to the formula Fe_3C, but the molecular weight is unknown.

A gravimetric method of estimation is given by Ledebur and Müller.† It is based on the assumption that the carbide is undecomposed, when the iron is dissolved in extremely dilute acids, hardening carbon being evolved as gaseous hydrocarbons, carbide, with graphite or temper carbon being left behind. The two latter are determined independently, and the carbide obtained by difference. Any error in their determination would appear in that of the carbide. Further, it has been shown that the carbide is decomposed by the most dilute acids (even acetic acid) and the greatest care must be taken to preserve it from contact with air, owing to its liability to oxidize.

It appears almost impossible to state the accuracy of this method. Probably it does not give results nearer than three or four per cent.

A method proposed by Jüptner von Jonstorff (*loc. cit.*) of estimating the carbide colorimetrically, by dissolving in dilute nitric acid at 80° C., comparing with a solution of known carbide content, is certainly not accurate to nearer than ± 5 per cent.

Hardening Carbon. — The chemistry of this important and interesting form of carbon has still to be elucidated. As the name suggests, it appears in hardened steels. Microscopic investigation has shown that hardened steels with less than 0.9 per cent carbon are almost homogeneous substances. The structures developed by etching are crystalline, and at the present time the view is held that hardened steels consist of solid solutions.

Dilute hydrochloric or sulphuric acid causes the evolution of a complex mixture of hydrocarbons, and it is very desirable that this reaction should be thoroughly investigated and explained. It has a vital bearing on the theory of the hardening of steel, about which so much has been heard in recent metallurgical discussions.

Hardening carbon is usually estimated by subtracting the percentages of the other forms of carbon from the total carbon. Consequently, the errors of the other methods appear in the result.

A colorimetric method is given by Jüptner von Jonstorff (*loc. cit.*), of about the same degree of accuracy as in the case of the carbide.

* "Zeitschrift für Anorganische Chemie," 1896, Vol. XIII.

† "Iron and Steel Institute," 1893, Vol. II, page 58.

FOUNDRY FANS AND BLOWERS*

AT the regular monthly meeting of the Pittsburg Foundrymen's Association held at Pittsburg on Tuesday, May 31st, the committee on fans and blowers appointed several months ago made a partial report. It was compiled at the request of the committee by Herbert E. Field, metallurgical engineer of Mackintosh, Hemphill & Co., from replies to a circular letter containing a list of questions as shown in the report. A paper read before the association by Thomas D. West resulted in the appointment of this committee and started the investigation into the relative merits of the fan and the blower. Tests are shortly to be made at the plant of Mackintosh, Hemphill & Co. by a number of experts in cupola practice, with a view to gaging more closely the merits of fans and blowers for foundry use, and the results of these tests will be given to the members of the Pittsburg Foundrymen's Association at the September meeting. The report as compiled by Mr. Field follows:

At the request of the committee on fans and blowers of the Pittsburg Foundrymen's Association, I have examined and classified the various replies to the questions which they sent out to foundrymen. From this classification, I have taken the following data, which may be of interest to the association. At the outset, I would say that it would be impossible to include all these items in this report. The lack of certain important details in most of the replies makes an accurate comparison impossible. Some of the replies, however, were very complete and indicated that a great deal of attention was paid to this department of the foundry work. They involved a considerable outlay of time, and on the whole I consider that the Association is to be congratulated in obtaining replies from so many representative foundrymen.

In submitting the following classification, I give the results as sent in. You will note, however, that some of the figures verge upon the impossible. It is not within the province of this report to distinguish between the correct and the incorrect, but rather to place before you, in as concise a manner as possible, the substance of the replies received.

* "The Iron Trade Review," June 2, 1904.

1. What appliances do you use for generating blast for your cupola, fan or pressure blower?

To this question thirteen firms replied that they were using pressure blowers, and seven, that they were using fans. It may be interesting to note in this connection that of the forty-six foundries in the list published by Mr. West in the 1896 edition of his book, thirty-three used fans, and thirteen pressure blowers. If we consider these figures as representatives, there has been a decided tendency in the last eight years towards pressure blowers.

2. State what power you use to drive your fan or blower, electric or steam, and give name and number, or size of fan or blower you use?

Seventeen replied to the first part of this question; of these, eleven used electricity for driving their fans and blowers. Two were direct-connected, five were belted to an electrically driven shaft. Four did not state the method of applying the power. Six used steam power; of these, three were directly connected to the engine, two were belted to a shaft, and one not stated. One used a gas engine. In reply to the second part of the question, one stated that they were using a number six fan, one a number seven, two a number eight, one a number nine, three number eleven and one-half, and one a number twelve. The number of blowers used were: one number four, three number seven, one number five and one-half, one number eight, one eighty-six foot, one forty-eight foot, one twenty-four foot. Three did not state the size of their blower. It is difficult to make comparisons in the above, as I have not been able to obtain catalogues of all the makes represented. I have thus been prevented from giving all the figures and sizes, which would have been much more satisfactory.

3. Send rough plan and side view sketch of the position of our cupola, fan or blower, showing the diameter and length of all piping, also the form and bends of elbows, as well as the diameter of the fan's or blower's outlet and the cupola's opening that connects with the main piping; also state what kind and mark position of blast gauge on above sketch if you use one. Also give inside diameter of your cupola.

It would be impracticable to give, in a report like this, any

complete idea of the drawings and sketches submitted in answer to this question. These will, without doubt, be later submitted to the association for their inspection. The sketches showed all sizes, methods and differences imaginable, one blower being placed one hundred and twenty-three feet from the cupola. There was absolutely no uniformity in regard to design or methods used in connecting the blowers or fans to the cupola. The inside diameters of the cupolas were as follows: Two 42-inch cupolas, four 44-inch, one 46-inch, three 48inch, one 54-inch, one 58-inch, four 60-inch, one 62-inch, two 64-inch, two 66-inch, one 72-inch, and one 84-inch.

4. Give blast pressure at two or more intervals during a heat, and state from your observation the highest pressure your fan or blower is capable of producing.

5. State revolutions of fan or blower at any given time and the amount of horse-power required at the same intervals in connection with your blast pressure if you can.

The answers to these questions were so intimately associated that I have classified them together. I include a table which shows the size of cupolas, size of blowers, or fans, horse-power required, and the number of ounces pressure obtained.

Diam. cupola in inches	Blower size	Fan size	H. P.	Revolutions	Pressure in ounces	H. P. per ounce
84	86 in.		60		16	3.52
72	68 in.		50		18	2.72
66	45 in.		41	180	16	2.57
66	No. 7		25		15.5	1.63
64	No. 6				14.5	
64	No. 7			160	14.5	
62		No. 11.5		1,546	9	
60	No. 7.		60	68	13.5	4.44
60		No. 12	43	190	11	3.94
60		No. 11.5	44	1,780	12	3.66
60		No. 11.5	34	1,769	8	4.25
58	No. 5.5		37	232	9	4.11
54	68 in.		50		18	2.78
48			17	190	12.5	1.36
48	24 in.		25	225	14	1.72
48		No. 9	26	1,750	10.5	2.48
46		No. 7	20	2,500	10	2.00
44		No. 8	40	1,546	9.5	4.21
44		No. 6	20	2,800	10.5	1.90
44	No. 5.5		20	142	10.5	1.90
44	No. 6			156	8	
42	No. 6			120		
42	No. 4			213		

I have also included the number of revolutions whenever they were given. I have divided the horse-power by the number of ounces pressure obtained in order to get an arbitrary figure for the sake of comparison. The highest horse-power per ounce pressure given was one to four and four-tenths horse-power for the blower, and one to four and three-tenths horse-power for the fan. Both these were used on 60-inch cupolas. The lowest horse-power per ounce pressure was one and four-tenths horse-power per ounce on a 48-inch cupola where a blower was used; the next was one and seven-tenths horse-power per ounce on a 48-inch cupola, where a blower was also used. The lowest horse-power per ounce for a fan was one and nine-tenths horse-power. The average horse-power per ounce in the foundries using blowers was two and seventy-eight hundredths, and for those using fans, three and two-tenths. Inasmuch as blowers were used on all the larger size cupolas, these returns very much favor the blower.

6. State whether you use coke or coal, or a mixture of both, in your cupola for melting.

Seventeen reported as using coke alone, and two as using a mixture of coal and coke.

7. If you have changed from fan to pressure blower at any time, give your reasons for having done so, also any tests that have led to these conclusions. In general the association would like your opinion of the advantages of fan and pressure blowers, if you have had any experience in using both.

Some three or four of those who replied had changed from a fan to a blower, but none reported as having changed from a blower to a fan. A few of the reasons given for these changes might be interesting. One reports that he had two 54-inch cupolas running alternately; to furnish the power for the same, he had two 48-inch fans. These were connected with a 40-horse-power engine. Even when he had connected both fans independently to the cupolas and divided his wind box so that he could not direct one fan against the other, he could not get sufficient wind. He replaced the two fans with one 68-inch blower, and used a 50-horse-power motor, and everything worked satisfactorily. Another gave as his reason for changing from fan to blower that he could increase the blast capacity without increasing the size of his engine or boiler. Another changed from fan to blower on account

of the annoyance caused by a slipping belt. He also stated that there was a great saving of power and that he was able to gear his blower directly to a motor. Another changed from a fan to a blower because a blower used less power.

8. State if at any time in your experience the base suggested for standard tests in paragraphs 8 and 9, Mr. West's enclosed paper, would have proved beneficial to you, and also if you would approve of such being established for the benefit of trade.

With two exceptions, the answers to this question were all in the affirmative. One of these stated that he considered that the horse-power was too high for standard. While the most of the writers signified that they considered that such standards would be a benefit, it is rather doubtful whether they really understood what this meant, as those who had blowers voted in the affirmative as well as those who had fans.

Remarks

It has been proven without a question that the fan for certain purposes has a greater efficiency than the blower, but what we are directly concerned with now is, has it a greater efficiency for cupola work? We must take into account the amount of metal melted per hour, temperature of the metal, and the fuel consumed, as well as the original cost of the fan or blower, the depreciation and power required to run it.

The answers sent in are of little or no help in solving this problem. Mackintosh, Hemphill & Co. have undertaken to determine which is most efficient at their works, the positive pressure blower or the fan. The committee on fans and blowers of the Pittsburg Foundrymen's Association has secured for them the use of the Connersville blower and a Sturtevant fan for this test. Everything will be done to make the test a representative and satisfactory one. All the features of cupola practice which could in any way affect this problem will be taken into account in deciding which is the more desirable for foundry purposes.

ABSTRACTS *

(*From Recent Articles of Interest to the Iron and Steel Metallurgist*)

Cupola Fan Practice. W. H. Carrier. Read at Indianapolis Meeting of Foundrymen's Association, June 1904. Abstracted in "The Iron Age," June 23, 1904. — The object of this paper is to give reliable data relative to the operation of centrifugal blowers for cupola service, including the air supply required per pound of coke used and per ton of iron produced; the relation of pressure, size of cupola and speed of melting; the horse-power required for various sizes of cupolas at different pressures, corresponding to different ratios of melting; the relation of speed, pressure and capacity of centrifugal cupola blowers; the effect of piping resistance upon the pressure and horse-power. The author concludes as follows:

"The horse-power required to operate a cupola at any stated pressure is to an extent independent of the size of the blower, so long as it has sufficient capacity to supply the required amount of air.

"The melting capacity of a cupola under standard conditions varies with the pressure according to fixed laws.

"More horse-power is required per ton of iron melted at the higher pressures than at the lower ones.

"At a fixed speed the greatest horse-power is taken when

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* Note. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

the blower is running wide open, or at free delivery; the least horse-power is taken when the outlet is closed. The increase in horse-power is proportional to the increase in air delivery.

"The piping resistance decreases the air delivery and decreases the horse-power at a fixed speed, but increases the horse-power when the fan is speeded up to give the same pressure at the cupola.

"The centrifugal blower presents some advantages over the positive blower, from the fact that better results can be secured at lower pressures, but there is a greater uniformity of blast pressure, and it offers a flexibility in regulation. With the exception of the belting, there is but little wear or deterioration; it will give as high efficiency after running 20 years as when first installed. On the other hand, the positive blower, owing to the friction of the contact surfaces, wears and deteriorates rapidly, and its effect, while high at the beginning, decreases rapidly, owing to the leakage caused by the wearing away of the contact parts." **No. 190. A.**

Result of an Investigation of the Durability of Paints for the Protection of Structural Work. By Robert Job. "Journal of Franklin Institute." July, 1904. 7,200 w., illustrated. **No. 191. C.**

Foundry Costs. Their Analysis and Reduction. Henry Hess. "Iron Trade Review," June 30, 1904. 7,700 w., illustrated. — A paper read before the Engineers' Club of Philadelphia. **No. 192.**

Early Use of 60,000 Pound Steel. J. T. Wagner. "Iron Trade Review, June 30, 1904." 4,500 w. — A paper presented to the American Society for Testing Materials, Atlantic City meeting, June, 1904. **No. 193. A.**

Electric Welding Development. Elihu Thomson. "Cassiers' Magazine," June, 1904. 2,500 w., illustrated. — The author describes the electric welding of iron and steel pipes, hoops and tires, wire fence, rails, chains, tubes, shells, etc. **No. 194. C.**

Lash Duplex Process for Steel Making. "Iron Trade Review," June 9, 1904. 3200 w., illustrated. — The article describes some patents which have been allowed recently to Horace W. Lash of the Garrett Cromwell Engineering Co.,

of Cleveland, Ohio, for improvements on the manufacture of steel. They relate principally to a modified arrangement combining the Bessemer converter with the open-hearth furnace, commonly known as the "Duplex" process. **No. 195. A.**

Specifications in the Foundry. David Reid. Read at the Indianopolis meeting of the American Foundrymen's Association, June, 1904. "The Iron Trade Review," June 23, 1904. 800 w. **No. 196. A.**

The Constitution and Properties of Silicon Steel. L. Guillet. "Comptes rendus," 137, 1052 (1903).—With up to five per cent silicon in iron, the silicon cannot be detected microscopically. With five to seven per cent silicon, part of the carbon is present as graphite, while the carbon is all changed to graphite when the silicon exceeds seven per cent. The author hazards no guess at the form in which the silicon appears after its concentration exceeds five per cent. A steel containing over five to seven per cent of silicon cannot be worked. "The Journal of Physical Chemistry," May, 1904. **No. 197.**

"The Foundry."—The July (1904) issue of "The Foundry" contains the following articles of interest:

"Foundry Accounting." By Kennett Falconer. (Paper read at the Indianapolis meeting of the American Foundrymen's Association.

"Value of the Chemist and Metallurgist to a Manufacturing Plant." By H. C. Laudenbeck. (Paper read at the Indianapolis meeting.)

"Molding Machine Practice." By F. W. Hall.

"Payment of Labor." By John Magee. (Paper read at the Indianapolis meeting.)

"The Engineer in the Foundry." By Dr. R. Moldenke. (Paper read at the Indianapolis meeting.) **No. 198. A.**

"The American Machinist."—Recent issues of "The American Machinist" contain the following articles of interest:

June 19. "English Results with High Speed Steel." Extracts from a paper read at a recent meeting of the Coventry Engineering Society. By J. M. Gledhill. (Concluded in June 16th issue.)

"Molding Machines." From a paper by G. C. Nielsen, read before the Chicago Foundry Foremen's Association, June 16th.

"Powdered Coal for Steel Annealing." By H. J. Travis. (This article will be reproduced in full in an early issue of *The Iron and Steel Magazine.*)

July 7th. "High-Speed Steel and the Manufacture of Armor-Piercing Projectiles." Editorial correspondence. The article describes the use of high-speed steel in the manufacture of armor-piercing projectiles by The Firth Sterling Company of Pittsburg, Pa. No. 199. **A** (each issue).

EDITORIAL COMMENT

Metallography and the Nursery

Apparently disappointed by the results obtained when applied to the examination of metals, an engineer attached to a well-known government institution betook himself and his microscope into a more promising field and investigated the constitution of ginger snaps. This was a stroke of genius, for he soon made the important discovery that the structure of a certain kind of ginger snaps greatly resembled that of a certain grade of steel. In order to preserve a permanent record of so momentous a revelation of nature's secrets, for the benefit of future generations, he proceeded to take photomicrographs of his preparation, and these he distributed broadcast to interested persons, with a generous spirit deserving of much praise. Some other men of science were not slow to perceive that this was a death blow to the new science of metallography, and had the courage to express their opinion in public meetings, where their statements were received with emotion.

Looking at this matter a little more seriously it is evident that this performance is just as meaningless as the sucking of thumbs and just as instructive. Thumb sucking is a harmless and innocent enough occupation, and seeing that it affords some pleasure to the performer, should not be interfered with. When, however, it is performed in public, during business hours, and when our attention is claimed for it at the expense of some other more worthy pursuit, it is time to remind the performer that the nursery is the proper place for the full and undisturbed enjoyment of his occupation.

The Practical Value of Metallography

Considerable difference of opinion seems to prevail concerning the value of the microscope in connection with practical steel making and steel testing. The microscopical examination of steel is constantly attracting new recruits: steel makers and steel consumers who had hitherto refrained from installing metallographic

outfits in their laboratories are almost daily joining those who before them had made room for the microscope. But we also hear of manufacturers expressing their disappointment at the results obtained by this method of testing and investigation. Some engineers and metallurgists report important results and highly praise the value of the microscope, others deny its practical value, while others still would hold it to ridicule. The methods employed by some of the last class have been illustrated in the foregoing paragraphs and their noise may be dismissed without further attention. But how shall we account for the claim of some engineers that the microscopical examination of metals has little or no practical value? We think that this class of men may be divided into two groups: (1) those who have never impartially and conscientiously looked into the matter and who, therefore, are not qualified to pass judgment, and (2) those who have actually given a trial to metallographic methods and who have been disappointed in the results. The opinion of the former group is not entitled to recognition. Their attitude is a question of temperament and education, and we do not propose to discourse here on such themes. We shall confine our remarks to the attitude of the disappointed ones, as they only make a claim deserving attention. We think that we can account in a large measure for their feeling in the matter. It seems to us that many of them, after introducing metallographic methods into their laboratories, often reluctantly, expected that they would eliminate all the troubles pertaining to steel making and steel working, and which hitherto chemistry and ordinary physical tests had been unable to do. Frequently, also, they confided the work to an inexperienced and youthful person, or to an employe already severely taxed with other duties, and then laid back to await results. Such unreasonable attitude was bound to lead to disappointment and at this they assumed a new attitude more unreasonable still, consisting in a wholesale condemnation of the practical value of metallographic methods. Such a course strikingly recalls the tribulations of the chemist when he first endeavored to obtain a foothold in steel works. He also was shunned at first, and it took a number of years before his proper place was found with full knowledge of his limitations, but also with full knowledge of his value, and now we wonder that iron and steel could ever have been made without the assistance of the chemist. We venture to predict that the time will also come

when the making and intelligent treating of steel without the assistance of the microscope will likewise be o source of wonder. History, however, must repeat itself, and the evolution of the metallographist bids fair to be an exact duplicate of the evolution of the iron chemist: the same landmarks indicate his course: distrust, reluctant acceptance, unreasonable and foolish expectations from his work, disappointment because these expectations were not fulfilled and finally the finding of his proper sphere and recognition of his worth. The metallographist has passed through the first three stages of this evolution, is emerging from the fourth and entering into the last. For so young a candidate for recognition in iron and steel making, this record is on the whole very creditable.

The Microscope in Steel Works

In the foregoing paragraphs we have expressed the belief that much of the disappointment of some engineers at the results yielded by metallographic methods was due to unreasonable expectation and also to the fact that the work was seldom entrusted to properly qualified persons. A laboratory boy with no knowledge of chemistry whatever may be trained to make numerous and trustworthy determinations of silicon, but woe to the manufacturer who believes that he can turn out microscopical determinations in the same manner. There are some metallurgists and engineers, moreover, who cannot see any value in a testing method unless it is susceptible of application, in a routine like manner, every day of the week, like, for instance, the determination of " color carbon " in steel. Then only can they conceive a value of the method which can be translated in dollars and cents. Metallographic methods have hardly reached a point where they can be applied in this systematic manner to numerous samples each day, and possibly may never reach it. Shall we infer from it that until then they can be of little practical value? To assert it would indicate a singular lack of intelligent thinking. If the microscope is not, at present at least, used for routine testing, it is nevertheless an invaluable instrument in the steel works laboratory; one to which we can rightly look for the adjustment of all questions related to the heat treatment of steel, so long neglected, but now receiving the attention it deserves. This is essentially the field which the microscope may call its own because it is pre-

cisely here that chemistry fails us, and it is a field which is daily becoming of greater importance. In a general way, moreover, we should look to the microscope for assistance in accounting for the many results which are unexplained by other testing methods — and let us not condemn metallography if it fail to furnish the explanation in every instance; let us, on the contrary, recognize its importance if it solve but a small proportion of these problems. One such solution may pay many times for the expense incurred in installing the necessary outfit and in conducting the work. Finally in the light of what has already been accomplished by their use, we may consider metallographic methods as one of the most promising and effective means of advance and progress in the art as well as in the science of the metallurgy of iron and steel.

IRON AND STEEL METALLURGICAL NOTES

The Creeping of Rails. — There is a certain amount of mystery about the creeping of rails, because, although it is a well-recognized fact, no one so far has come forward with an explanation that satisfies the whole problem. Some people hold that the line always travels in the direction of the traffic; others that it invariably goes downhill; others believe that the right rails move more than the left; and others again that the outer rail of a curve is the more peripatetic. Some careful measurements have been made on a number of lines in America, and a paper on the subject has been sent to the American Society of Civil Engineers by Mr. S. T. Wagner. Nothing could be more satisfactory than this latest inquiry, for it gives some support to everybody's views. The method of taking observations was roughly as follows. Stakes were driven into the ground at some distance at each side of the line, a transit instrument was set up over one stake and sighted on the other; then a center pop was marked on the rail in the line of sight—that was the datum mark. Measurements were taken at intervals of about a fortnight, by placing a card with a notch in its edge against the datum pop, and marking on it by the aid of the transit the amount of movement. The diagrams are given in the paper with a lot of useful particulars — the facts may be summed up as follows. At 21 points the two rails moved equally, at 8 the right moved most—the right crank leads on all the engines — at 3 the left rail showed greatest travel. In seven cases out of twelve the greatest creeping occurs on down gradients, on five there is practically no difference. The condition of the road bed is the main factor; where it is bad, or where the line runs over a swampy embankment, the creeping reaches its maximum. Hence the now generally accepted theory that the action is due to the bending and unbending of the rail receives some support.

From an inspection of the diagrams it is evident that the creep is not always in the direction of the trains. Out of thirty-two sets of diagrams — that is, for double lines up and down — we note that in at least seventeen cases either one or both rails had moved backwards at the time one or more of the observations were made. In one case the right rail has moved steadily backwards; the left rail steadily forwards. The gradient, too, appears to have some influence, as there seems to be a tendency to go down hill on both up and down lines, although there are instances where the rail climbs with the trains. On a bad road there is no doubt about the line moving forward, but on a gradient it moves more swiftly down than uphill. When more observations have been collected it may be possible to resolve all the conflicting facts by a careful analysis of the conditions, and so arrive at some clear and precise views. At present we have not got much "furtherer," except for the certainty that creep is not nearly so serious as the plate-layers suppose. — "The Engineer," June 10, 1904.

Styrian Steel. — At the March meeting of the Birmingham Association of Mechanical Engineers, England, Mr. R. B. Hodgson read a paper on Styrian steel, in which he points out the great antiquity of the iron and steel industry of the Styrian ore mountain; iron and steel having been manufactured by the direct process there for over 2,000 years. The excellence of the iron produced from the spathic ore-body that lies between the present villages of Eisenerz and Vordenberg was known by the Romans, with whom Noric iron was a synonym for excellence. This ore is very low in phosphorus, sulphur and copper, and relatively high in manganese. The Styrians smelted this ore with charcoal fuel, producing a white cast-iron which, by subsequent treatment in the old Styrian open-hearth furnace, they made into steel containing impurities not exceeding 0.03 per cent. To this low per cent of impurities the excellence of the steel is due. The extensive works of Bohler Brothers include blast-furnaces at Vordenberg, numerous charcoal steel refineries, and steel casting works at Kapfenberg. The industry is of great interest from an historical standpoint, since the processes now used are merely modifications of those known to the Romans. — "Engineering and Mining Journal," June 9, 1904.

The Hard and Soft States in Metals. — At an ordinary meeting of the Faraday Society held on June 9th at the Institution of Electrical Engineers, Mr. G. T. Beilby read a paper on "The Hard and Soft States in Metals." The wide range of the phenomena which are directly or indirectly associated with the hard and soft states in metal indicates that a knowledge of these states is of fundamental importance. An exclusively crystalline theory of metal structure even when stretched to its widest limits is insufficient fully to explain these phenomena. But the crystalline is not the only form of solid aggregate; the movement of the molecules in the liquid state may be so suddenly arrested that they have no time to fall into the regular formation of the crystalline state so that the solid which results is amorphous not crystalline. A suddenly congealed liquid may be likened to an instantaneous photograph of the rapidly moving molecules of the liquid state.

The views here advanced are based on the author's earlier observations on surface flow in crystalline solids. The evidence afforded by the micro-structure has been supplemented by observations on the other properties of metals in the hard and soft states and the view is now advanced that these states are perfectly distinct phases. This is shown by the mechanical, electrical, optical and thermo-chemical properties as well as by the micro-structure. The soft phase C. is crystalline and the hard phase A. is amorphous.

The transformation of A. into C. is effected by heat and takes place at a definite transition temperature. On either side of the transition point the various properties are characteristic and distinct; for instance, an E. M. F. of 120 micro-volts may be developed in a thermo-junction of silver in the two phases. The E. M. F. falls to zero after the junction has been heated to 260° for a few seconds. Silver leaf which is opaque and highly reflecting below the transition temperature becomes transparent and very much less reflecting if kept for a time at a temperature a little above that point.

The transformation from hard to soft is thermally irreversible but it is readily effected mechanically. This reverse transformation — soft to hard — takes place when the metal

is deformed by overstrain however slight. It takes place through an intermediate mobile phase in which the molecules have a freedom analogous to that in the liquid phase. This freedom is produced by motion directly imparted to the molecules during the slipping of one portion of the material over another. The state of the mobile phase is somewhat analogous to that of an undercooked liquid. This transformation C.-M.-A. while it occurs at every moving surface, does so as a rule in extremely thin layers. The layers of the hard phase which result supply a rigid casing for the unaltered crystalline elements and thereby give a granular and cellular structure to metal which has been overstrained by having any kind of work done on it. The co-existence of the two phases in this way accounts for the variety of structure which may be developed in malleable and ductile metals.

The Iron and Steel Institute — American Meeting. — The Secretary of the Institute has issued a provisional program for the American meeting, from which we extract the following:

It is expected that most of the members will arrive in New York on Friday, Saturday and Sunday, October 21st, 22d and 23d. The headquarters will be at the Hotel Astor at 44th Street, and Broadway, the newest and best equipped hotel in New York City, which will be open to the public by September 1st. For the entertainment of the members during their three days stay in New York, a Reception Committee has been formed including the following gentlemen: Mr. James A. Burden, Chairman; Mr. G. W. Maynard, Vice-Chairman; Mr. Stephen W. Baldwin, Chairman, Finance Committee; Mr. L. W. Francis, Chairman, Invitation Committee; Mr. C. A. Moore, Chairman, Reception Committee; Mr. E. E. Olcott, Chairman, Transportation Committee; Mr. Thos. Robins, Jr., Chairman, Entertainment Committee; Mr. T. C. Martin, Chairman, Banquet Committee; and Dr. R. Moldenke, Secretary.

Monday, October 24th. — The New York Committee will arrange for optional excursions to power houses, bridges, industrial establishments, universities, the navy yard, subway and other places of interest in New York, with

boat trips around the harbor and drives in the parks for the ladies of the party, during the morning and afternoon, with the opening of the Annual General Meeting of the Institute in the evening, followed by a reception.

Tuesday, October 25th. — The daylight hours will be devoted to an excursion up the Hudson on a specially chartered Albany boat, stopping at West Point, where the United States Military Academy is situated.

Wednesday, October 26th. — In the morning and afternoon there will be two meetings of the Institute for the reading and discussion of papers. In the evening the Institute will entertain the Reception Committee at dinner at the Waldorf-Astoria. For this evening a theater party is to be arranged for the ladies accompanying members.

Thursday, October 27th. — The party will leave New York in the morning for Philadelphia.

Friday, October 28th. — This day will be spent in Philadelphia.

Saturday, October 29th. — In the morning special trains will leave for Washington where there will be a reception in the evening by the President of the United States.

Sunday, October 30th. — Will be spent in Washington, no special program being arranged.

Monday, October 31st. — In the morning the party will leave for Pittsburg, arriving there in time for evening dinner.

Tuesday, Wednesday and Thursday, November 1st, 2d and 3d. — These days will be spent in Pittsburg.

Friday, November 4th. — The main party will leave in the morning for Cleveland.

Saturday, November 5th. — The party will leave Cleveland and arrive at Buffalo, spending the night and Sunday there. Those who wish to stop at Albany to visit the General Electric Company's plant, can do so, both parties arriving in New York on the evening of Tuesday, November 8th, in time for the steamer leaving for England on Wednesday, November 9th. During the stay in Buffalo the party will be taken to Niagara and given ample opportunity to see the Falls. The party travelling entirely by day, will only have to take two or three meals on the trains; and it may be estimated that the total cost of the main trip will be £25.

St. Louis Exhibition Excursion. — For the convenience of members desirous of visiting the St. Louis Exposition, arrangements will be made for a limited number to leave Pittsburg for St. Louis and Chicago, returning to New York in time for the steamer leaving Saturday, November 12th. This trip will necessitate three nights being spent in sleeping cars, and the approximate cost will be £35. The special St. Louis party will leave Pittsburg on the evening of Thursday, November 3d, arriving at the Exposition grounds on the morning of Friday, November 4th, spending Saturday and Sunday at St. Louis and leaving Monday night for Chicago. The party will leave Chicago on Tuesday night, November 8th, for Buffalo, spending Wednesday, Thursday and part of Friday there.

REVIEW OF THE IRON AND STEEL MARKET

The general downward swing in prices and production in the iron trade has continued during the past month, but in a less pronounced manner than in the two previous months. There has even been an effort in some quarters to make it appear that the trade is on the mend, but there is little doubt that this sentiment was originated in Wall street, and for ulterior purposes. Certainly there has been no marked increase in demand, and it will be well to adhere to the ideas formed a few months ago, that 1904 would be an " off " year in the iron trade, with a decided improvement in store for the early part of 1905.

In our report a month ago we expressed the opinion that pig iron production, which has been at the rate of 19,400,000 tons annually in April, would decline to a rate of about 14,000,000 tons by August 1. The statistics since presented by " The Iron Age " show a rate of production on July 1 of 14,500,000 tons, and we are disposed to think now that the rate on August 1 will be less, rather than more, than we predicted. There are no statistics to show the actual stock of pig iron in the country, those currently presented referring only to unsold stocks in the possession of merchant furnaces. The actual stocks are much larger and will necessarily defer for many months any important increase in production. Stocks of crude steel and finished products, while not large in proportion to annual production, are large in proportion to those usually carried.

Meetings were held early in July of the principal pools and associations controlling prices of semi and finished products, and such prices were reaffirmed. The action is not particularly significant, inasmuch as no other outcome was expected, and it is a well-accepted principle in the iron trade that prices are more likely to decline in the face of some tangible demand, than when this is absent. The crucial test of the present price structure may not come therefore for some time yet. Obviously the structure is not a sound one, since such lines as rails, plates and shapes are held

at the same figures as prevailed during the years of extreme prosperity, while pig iron, together with many finished steel products, are much lower. These were reduced through the stress of competition, yet competition will not be lacking in the other lines, since the productive capacity of the country is at the present day considerably greater than when demand was at its height.

The low point on northern pig iron, made from Lake Superior ores, was reached in the summer of 1897, when Bessemer and No. 2 foundry iron sold at $8.75 to $9.00, f.o.b. valley furnace. In the most adverse circumstances such a level could not again be reached, since similar priced ores cannot be had. The richest of the Lake Superior ores were then being sold in the market under sharp competition, mined principally by concerns who held their ore lands in fee, and had acquired them very cheaply. The principal merchant ore producers, who would now be disposed to enter into sharp competition, are miners on royalty, which makes a difference of from 20 to 40 cents a ton. Besides this, the richest ores are no longer purchasable in the market. The merchant furnace must be content with ores considerably below the standard, and requiring close to two tons of ore to one of pig ron. As ore cost is largely a matter of freights, this is a telling item.

The evidence is that pig iron has approximated, if not actually reached, its bottom on the present movement, and whatever adversities the trade may yet have to bear will be in the line of the disruption of pools and associations which have been holding some steel lines at fictitious prices. Even with the worst, there is no doubt that next year will be a much better year than this for the trade, and a period of perhaps half a dozen of moderately prosperous years is well nigh a certainty.

Pig Iron. — The market is rather irregular and prices can be quoted only approximately, on the following basis, f.o.b. western Pennsylvania or Ohio furnace: Bessemer, $11.60 to $11.75; No. 2 foundry, $11.50 to $11.60; gray forge, $11.00 to $11.15; basic, $11.50 to $11.60. Prices delivered Pittsburg are 75 to 85 cents higher. In the south the market is apparently firmer, and $9.25, f.o.b. Birmingham, is the minimum quotation on No. 2 foundry, with most producers quoting $9.50. This is clearly an advance of 25 cents a ton in the month, but little is being done at the advanced figures, and the advance may be due principally

to a strike of coal miners which has caused the idleness of half a dozen furnaces.

Steel. — It is claimed that the billet association prices, $23.00 for billets and $24.00 for sheet bars, Pittsburg, Wheeling or valleys, are being mantained, but in the absence of actual transactions of importance the bearing of these claims is not necessarily great.

Finished Materials. — Official prices of merchant steel pipe were reduced July 1 by from 1½ to 2½ points, and of boiler tubes from 3½ to 4½ points, according to size, a point being approximately $2.00 per net ton. Occasionally there is shading even of the new prices. Wire products are being quite generally shaded by from $2.00 to $3.00 per net ton, the official price of wire nails being $1.90, base, f.o.b. Pittsburg plus freight to destination, in carload and larger lots to jobbers. Sheets are only fairly firm at 2.10 cents per pound for No. 28 gauge. Plates remain unchanged on the basis of 1.60 cents, Pittsburg, for tank quality. There has been no change in shapes, rails, or merchant steel bars. Common iron bars are quoted at 1.30 cents, base, Pittsburg.

STATISTICS

Large Exports in Steel Rails. — The Government statistics of imports and exports in May at last show results for the large export orders of steel rails which were taken some time ago. The exports of steel rails in May amounted to 41,388 tons, or nearly 3,000 tons more than the exports in the first four months of the year. Rail exports have now reached really important proportions, since the May movement was at the rate of a trifle over a half a million tons a year. Pig iron exports in May showed a decrease, the amount, 2,031 tons, being the smallest of any month this year. Crude steel exports show an increase of over 3,000 tons above April, but still did not reach the tonnage of March. The following table shows our exports by months of pig iron, crude steel and steel rails:

Exports in 1904, Gross Tons

	Pig Iron	Steel	Rails
January	6,742	1,860	1,740
February	3,429	26,205	8,465
March	3,954	36,908	17,873
April	2,898	28,276	10,460
May	2,031	31,527	41,388
	19,054	124,776	79,926

The total exports of those iron and steel products of which the weight is reported amounted to approximately 107,500 gross tons, showing an increase of 32,148 tons over April, but as the increase in crude steel and steel rails was 34,179 tons, there was a net decrease in other items. The following lines showed slight increases: Scrap, wire rods, iron sheets, steel sheets and structural shapes. The following items showed slight decreases: Bar iron, bar steel, iron rails, hoops, tin plate, wire and cut and wire nails. The decrease in wire, however, was inconsequential, being from 11,549 tons

to 11,476 tons. The total tonnage of exports for the eleven months of the fiscal year was approximately 557,000 tons against 276,000 tons in the same period a year previous.

The imports of iron and steel in May showed an increase of about 1,000 tons over April, being approximately 25,000 tons. This is due wholly to an increase in iron and steel rails from 3,903 tons to 8,918 tons, which more than makes up for decreases in various minor lines. It is quite probable that these rails imported are really scrap. In fact, we know of one transaction which would make up a large part of this tonnage, an American importer having purchased old rails abroad for rerolling purposes, expecting them to be dutiable as scrap, whereas the Government held them for a higher duty, and the loss was such that similar transactions will not be made in the future. The imports of pig iron in May were 5,184 tons, against 7,713 tons in April. — "The Iron Trade Review," June 30, 1904.

American Pig Iron Production. — The usual midsummer pig iron statistics are presented by James M. Swank, with the production of charcoal iron omitted, the coke and anthracite pig iron production amounting to 7,956,392 tons of 2,240 pounds. This compares with previous half years as follows:

United States Coke and Anthracite Pig Iron Production, Tons of 2,240 Pounds

First half, 1903	9,473,723
Second half, 1903	8,029,845
First half, 1904	7,956,392

The production of charcoal iron (including 927 tons of mixed charcoal and coke made in the first half of 1903) was 233,644 tons in the first half of 1903, and 272,040 tons in the second half. Accordingly, the total production of pig iron in the United States in the first half of 1904 may be taken to have lain between 8,100,000 tons and 8,200,000 tons, or at the rate of between 16,200,000 and 16,400,000 tons per annum, against 18,-009,252 tons in 1903 and 17,821,307 tons in 1902. The comparison fully bears out the general opinion which has been held since late last year that the continued breaking of annual records, which began in 1897, would end with 1903.

RECENT PUBLICATIONS

Foundry Nomenclature, by John F. Buchanan. 225 5 × 7-in. pages. E. & F. N. Spon, Ltd. London. 1903. Price, $2. — This little book contains over 2,000 words, terms and phrases, of special import and application in the foundry, as well as valuable notes on foundry practice, appliances, materials, metals, test-bars, cast iron scrap, shop receipts, useful memoranda, rules and tables. While appreciating the usefulness of the book we must take exception to the definition of many terms. A few instances will justify our stand. Acid steel is said to be "steel prepared by the acid process in the Bessemer converter," no allusion being made to acid open-hearth steel. Allotropy is defined in the following vague and obscure manner: "The existence of the same element in more than one usual condition." Blackband is said to be "a well known iron ore," a definition hardly descriptive of its nature; if it is so well known as not to require description it should have been left out of the vocabulary. Blow-hole is said to be "an air hole in a casting," a very misleading definition, for it naturally suggests that blow-holes are caused by the emprisonment of "air bubbles," whereas they are due chiefly, if not exclusively, to the escape of occluded gas. Ferro is described as being "a prefix indicating ferrous iron as an ingredient," ferro-aluminium, ferro-manganese and ferro-sodium being cited as examples. We think that it will not be accepted that ferro used as a prefix implies the presence of iron in the ferrous condition and the instances mentioned do not support the contention. Gangue is described as "silicious matter, constituting the matrix of some ores." What if that matrix is not silicious? Kish is said to be "grit or scum in metals." Our understanding is that by this term kish is meant the graphitic carbon which floats to the top of highly carburized liquid cast iron. It is said that matte in the case of copper consists principally of sub-sulphides and about 40 per cent of *metallic copper.* Several French words and expressions are ill-spelled, as for instance *cire perdu* instead of

cire perdue, moire instead of *moiré, verde antique* instead of *verd antique.* The book is well printed on good paper.

Traité Théorique et Pratique de Métallurgie Générale, by L. Babu. 588 6 × 9-in. pages; 148 illustrations; cloth binding. Librairie Polytechnique, Ch. Béranger. Paris. 1904. Price, 25 frs. — The author of this excellent book is chief engineer of mines and professor at the National School of Mines (France). In his introduction he rightly remarks that the actual tendency of metallurgy is to approach more and more a real science. The importance of the professional art decreases each day before the application of scientific methods, of the laws of chemistry and; in a general way, of the laws of the transformation of energy. Notwithstanding the very great differences in the manipulations required to extract the various metals from their ores, the various metallurgies are based upon many common principles, and Professor Babu's book is devoted to a study of these principles. The book is divided into sixteen chapters as follows: Ores, Capital, Work, Energy in General, Elastic Energy, Kinetic Energy, Electrical Energy, Chemical Energy, Mechanical Energy, Thermal Energy, Theory of Combustion, Production of Heat, Utilization of Heat in Metallurgical Furnaces, Recovery of Heat from Waste Gases, Properties of Metals and Alloys and Methods Employed in Their Study, Slags, and Cinders. The subject is treated with method, clearness and authority; and the publishers are presenting it in a very attractive form.

National Iron and Steel, Coal and Coke Blue Book. Second edition, by B. H. Morwood. 891 9 × 5½-in. pages. R. L. Polk & Co. Pittsburg, Pa. Price, $7.50. — This is an exhaustive and well classified directory of the firms, corporations and individuals engaged in the production of iron and steel, coal and coke in the United States. It includes the following lists: Iron and Steel Manufacturers, grouped as to character of works; Iron and Steel Manufacturers, descriptive and alphabetical; Directors, Officers, Managers, in alphabetical order; Blast-Furnaces, Iron and Steel Works, arranged by states; Producers of Anthracite Coal, alphabetical; Producers of Bituminous Coal, alphabetical; Coal and Coke Producers, by states and districts. The value of this book to the iron and steel trades need not be insisted upon.

Lectures on Iron Founding, by Thomas Turner. 136 5 × 7½-in. pages; 53 illustrations. Charles Griffin & Co. London. 1904. Price $1.50. — This book consists of six evening lectures on Iron Founding, delivered by the author at the University of Birmingham, England. The subject is briefly and still quite exhaustively treated; its presentation is clear, practical and representative of modern thought and methods. This excellent little book is sure to be warmly welcome by all engineers and metallurgists interested in foundry work.

The Phase Rule and Its Applications, by Alex. Findley. 313 7 × 4½-in. pages; 118 illustrations. Longmans, Green & Co. London. 1904. Price, $2.50. — The study of alloys, including steel and other iron alloys, has in recent years been conducted along strictly scientific lines. In order to obtain accurate information regarding their constitution, their fusibility curves and microstructure have been closely examined and these methods naturally led to the applications of Gibb's phase rule to the study of alloys. The phase rule has thus become part of the necessary knowledge of the student of scientific metallurgy. In the book we have before us, this subject is presented in a highly satisfactory manner and it will prove of much assistance to students. The book is prefaced by an introduction on the Study of Physical Chemistry, by Sir William Ramsay.

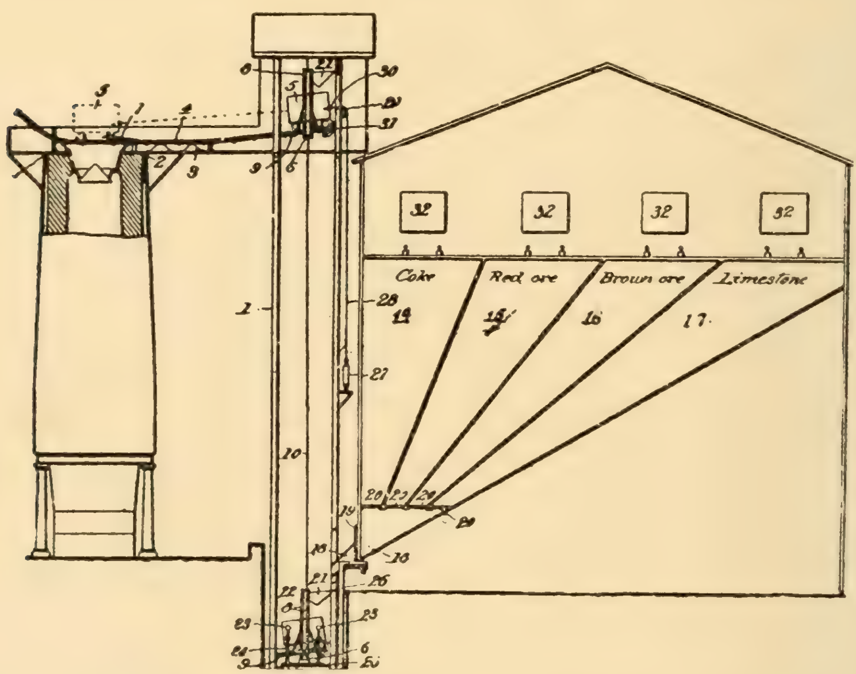
Fowler's Mechanical Engineers' Pocket Book. 441 6 × 4-in. pages. Scientific Publishing Co. Manchester, England. 1904. Price, leatherette and red edges, 1/6 net; leather and gilt edges, 2/6. — Advantage has been taken in the preparation of the 1904 edition of this pocket book to thoroughly overhaul its contents with a view to bring the matter up to date and correct any typographical errors not previously detected.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

760,189. Plant for Feeding Metallurgical Furnaces. — A. P. Gaines, Bessemer, and E. R. Cox, Jr., Birmingham, Ala. In plant for feeding materials to furnaces, combination with furnace, of vertical hoist, bridge connecting furnace with hoist, cage operating in hoist, car carried by cage and adapted to traverse bridge to furnace for discharging ma-



terials therein when cage is at upper landing, one or more bins provided with chutes arranged to deliver material into car while held stationary on cage at landing, and means for weighing loaded car at lower landing before hoisting.

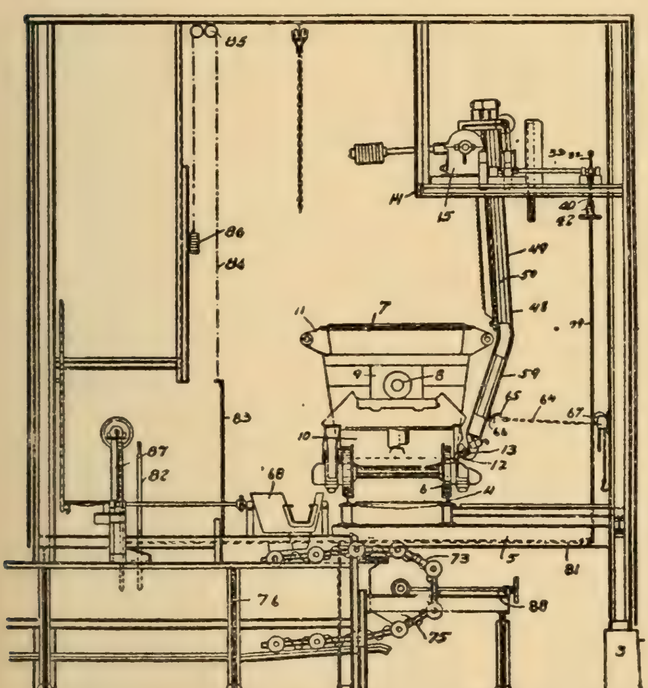
760,858. Rolling-Mill. — Victor E. Edwards, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass. The combination with a series of pairs of rolls for the continued reduction of a rod and arranged in horizontal alinement, of a series of carved repeaters connecting the successive pairs of rolls and arranged in a series of concentric curves of increasing radius as the reduction of the rod progresses.

760,873. Hot-Blast Valve. — Julian Kennedy, Pittsburg, Pa. A hot-

blast valve casing formed in two sections with clamping-rings at their adjacent ends, a valve-seat between the rings, and clamps arranged to draw the rings together and having thereon means for forcing the rings and casing-sections apart to release the valve-seat.

761,251. Coke-Quenching Apparatus. — Charles S. Price, Westmont, Pa. The combination with a retort coke-oven, of a quenching apparatus consisting of a covered receptacle of considerably greater width than the coke-oven, said apparatus being provided with a door-opening adapted to register with that of the coke-oven, a series of water-spray pipes mounted within the upper portion of said receptacle, and means for supplying and regulating the flow of water therethrough.

761,319. Ladle-Tilting Device. — William J. Patterson and Alfred M. Acklin, Pittsburg, Pa., assignors to Heyl and Patterson, Pittsburg, Pa., a co-partnership. In a ladle-tilting device, the combination with a tilting ladle, of a beam adapted to engage said ladle, a rack-bar pivoted to the upper end of said beam, the lower end of said rack-bar engaging a seat on said beam, whereby said beam has a certain amount of lateral play independent of said rack-bar, a pinion engaging said rack-bar, and mechanism for driving said pinion in opposite directions to raise and lower said beam.



761,393. Ladle-Tilting Device. — William J. Patterson, Pittsburg, Pa., assignor to Heyl and Patterson, Pittsburg, Pa. In ladle-tilting apparatus, the combination with a suitable tilting ladle having tilting mechanism, of a swinging frame, a power-driven shaft on said frame, means for connecting said tilting mechanism with said shaft, and means for driving said shaft in opposite directions.

761,525. Slag-Car. — George Mitchell, Naco, Ariz. In a dumping-car, the combination with a receptacle pivotally supported and top-heavy when full, of a worm-wheel connected with the receptacle, a worm to turn said worm-wheel and tilt the receptacle, eccentric supports for said worm, and means for turning said supports to throw the worm out of engagement with the worm-wheel to permit the receptacle to dump.

761,789. Coke-Oven. — Carl Schroeter, Chicago, Ill., assignor to Chicago Coke Oven Construction Company, Chicago, Ill. In a coke-oven of

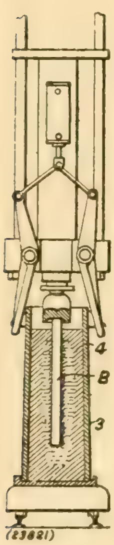
the character specified, the combination with a coke-retort having a heating-jacket entirely surrounding the same, of means for introducing air and fuel to said heating-jacket and burning it therein, and a regenerator comprising air-inlet and gas-discharge conduits one enveloping the other connected to said heating-jacket through which incoming air and the spent products of combustion are passed in opposite directions, substantially as described.

GREAT BRITAIN

15,032 of 1903. Silicon Steel. — J. W. Spencer, Newcastle-on-Tyne. Adding silicon to the extent of 0.75 to 2 per cent to mild structural steel, so increasing its strength without interfering with its ductility or weldability.

15,188 of 1903. Iron Ore Briquettes. — T. Rouse and H. Cohn, London. Method of hardening briquettes of fine iron ores mixed with lime, by treating them with hot air and steam.

23,821. Steel Ingots. — R. W. Hunt, Chicago, Ill., U. S. A. (7 Figs.) November 3, 1903. This invention relates to improvements in the art of casting steel ingots, and has special reference to the art of perfecting cast-steel ingots, particularly those intended to be made into rails. The invention, tersely defined, resides in an ingot-perfecting process that is characterized by the sudden, arbitrary cooling of the central or axial portion of the ingot at the moment preceding its removal from the mold, whereby the impurities and the gases are expelled from the center of the ingot. The process is further characterized by the addition of metal to the interior of the ingot, and the filling thereby of any pipe or cavity that may have been formed therein by the shrinkage of the metal, or the accumulation of gas within the walls or crusts of the ingot. In carrying out the process the molten steel is poured into a mold, and allowed to stand therein until the top crust of the ingot has formed. In the meantime a pipe or cavity may have begun to form within the ingot, the presence or absence of which may be due to many and varying conditions, all of which may be ignored because of the employment of a rod B, which is thrust through the top crust of the ingot 4 just before the mold 3 is stripped therefrom. This rod B is preferably heated, but is always cooler than the molten metal within the ingot, and its introduction serves to materially reduce the temperature within the axial portion of the ingot. This lowering of temperature checks the inwardly directed segregation of the metalloids and the gases in the molten metal, and operates to expel the same from the central portion of the ingot. The rod B should be of better steel than the ingot mass, and upon being thrust therein melts and raises the quality of the steel at the center of the ingot. The rods used in different ingots need not be of the same length, their size being determined according to circumstances. (*Accepted March* 2, 1904.)



HANS FREIHERR v. JÜPTNER

PROFESSOR OF CHEMICAL TECHNOLOGY IN THE ROYAL TECHNICAL COLLEGE AT VIENNA

The Iron and Steel Magazine

"...... *Je veux au mond publier d'une plume de fer sur un papier d'acier.*"

Vol. VIII — September, 1904 — No. 3

ALLOTROPIC TRANSFORMATIONS OF NICKEL-STEELS *

By L. DUMAS †

Special Contributor to The Iron and Steel Magazine

INFLUENCE of the Allotropic Condition on the Properties of Nickel-Steels. — It is well known that most of the physical properties of nickel-steels are so deeply altered when the metal passes through some thermal critical points that these modifications are supposed to be due to allotropic transformations. It follows from it that to study these properties we may study the allotropic changes and this is what was done at the steel works of Imphy, France. The results of our experiments are briefly given below.

* Received September 21, 1903.

† Louis Dumas was born in Paris in 1850. He studied at the "Ecole Centrale des Arts et Manufactures." After his graduation he remained at this school for three more years as assistant in General Chemistry and in Chemical Technology. The celebrated chemist, J. B. Dumas, was then president of the council of this school. Mr. Louis Dumas came also

I — Position of the Points of Allotropic Transformation of Nickel-Steel

Previous Results. — Le Chatelier, Hopkinson, Osmond and Guillaume have shown that nickel-steels undergo a transformation, called irreversible, at a temperature which is the lower the higher the percentage of nickel until a nickel content of 25 per cent is reached. With a larger proportion of nickel the transformation occurs at a higher temperature and becomes almost exactly reversible. The positions of the points of magnetic transformations — i.e., those temperatures at which magnetism disappears on heating or appears on cooling — have been ascertained by Osmond for a series of samples containing from 0 to 100 per cent of nickel. The curve resulting from the plotting of his results clearly shows the law, at first sight very abnormal, according to which the position of the transformation points varies.

Nickel-Steels Containing Carbon, Chromium and Manganese. — In Osmond's diagram the sample containing 25 per cent of nickel is the only one which is non-magnetic. Some non-magnetic steels exist, however, containing much less nickel. Osmond's curve refers to steels containing very little carbon, chromium and manganese, elements which are frequently found in nickel-steel. These elements exert a notable influence upon the position of the critical points, in some instances lowering the transformation point on cooling sufficiently to make the steels non-magnetic at the ordinary temperature. Our first experiments dealt with the study of the influence of these elements. Many samples of steel were prepared containing varying amounts of nickel-carbon, chromium and manganese, and their magnetic properties ascer-

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in contact with Pasteur, Sainte Claire Deville and Wurtz. From 1876 to the present day Mr. Dumas has been actively engaged in various departments of steel-making, holding responsible positions in important iron and steel firms, namely as chemist and later as blast-furnace manager at St. Dizier, engineer and later manager of the "Forges de Chatillon et Commentry." Mr. Dumas is at present the consulting engineer of the "Société de Commentry Fourchambault." He devoted much time to the study of the properties of nickel-steel containing large proportions of nickel, and he has published on that subject several excellent and authoritative papers which have contributed materially to the advancement of our knowledge of nickel-steel. In his work on nickel-steel he was closely associated with Mr. C. E. Guillaume, the distinguished associate director of the International Bureau des Poids et Mesures.

tained. Those which were non-magnetic at the ordinary temperature were immersed in cooling mixtures in order to ascertain the position of their transformation point. To this end both solid carbonic acid and alcohol which yield a temperature of — 78° C. and liquid air whose temperature is — 188°, were used.

By grouping together those samples containing nearly the same amount of nickel and classifying the members of each group according to their carbon-content, the marked influence of carbon was made apparent. The position of the critical point on cooling, and, therefore, the allotropic condition of the steel at the ordinary temperature, depend primarily upon the proportion of carbon.

The action of chromium appears to be confined to increasing the influence of carbon; the most notable fall of the critical points is produced by the simultaneous presence in the steel of carbon and chromium.

It is only upon the position of the irreversible points that carbon exerts so great an influence; it does not affect the position of the reversible critical points which explains why steels containing over 26 per cent of nickel, although carburized, are magnetic.

Osmond's austenite, which is a steel undergoing an irreversible transformation, although containing only iron and carbon, may be considered as a non-magnetic nickel-steel, in which the whole of the nickel has been replaced by carbon. In a similar manner Hadfield's non-magnetic manganese-steel may be considered as a nickel-steel in which the nickel is replaced by manganese. The influence of manganese and carbon upon the position of the points of irreversible transformation is similar to that of nickel, the effect of these three elements being cumulative. This consideration led us to treat as nickel-steels, not only those made up almost exclusively of iron and nickel, but also those in which these two elements are associated with carbon, chromium and manganese.

Determination of the Points of Transformation at Low Temperature. — In the cooling experiments to which I have referred the appearance of magnetism was not always a manifestation of the irreversible transformation characterized by the permanence of the new allotropic condition on again returning to the atmospheric temperature. It was sometimes due to a reversible transformation, the original allotropic state being again assumed as the temperature was raised. This was notably the case with a sample

containing 23.25 per cent of nickel and 0.85 per cent of carbon, which, when immersed in liquid air, returned to its original allotropic condition at about — 100° C. We must infer from this that 26 per cent is not the inferior limit of the nickel content of steels with a reversible transformation. A sample containing 27.72 per cent of nickel, and 0.25 per cent of carbon and 0.36 per cent of manganese exhibited, upon cooling, both transformations; first the reversible transformation in a bath of solid carbonic acid and then the irreversible transformation in a bath of liquid air. It follows from this that 25 per cent is not the upper limit of the nickel-content of steels with an irreversible transformation. Pre-

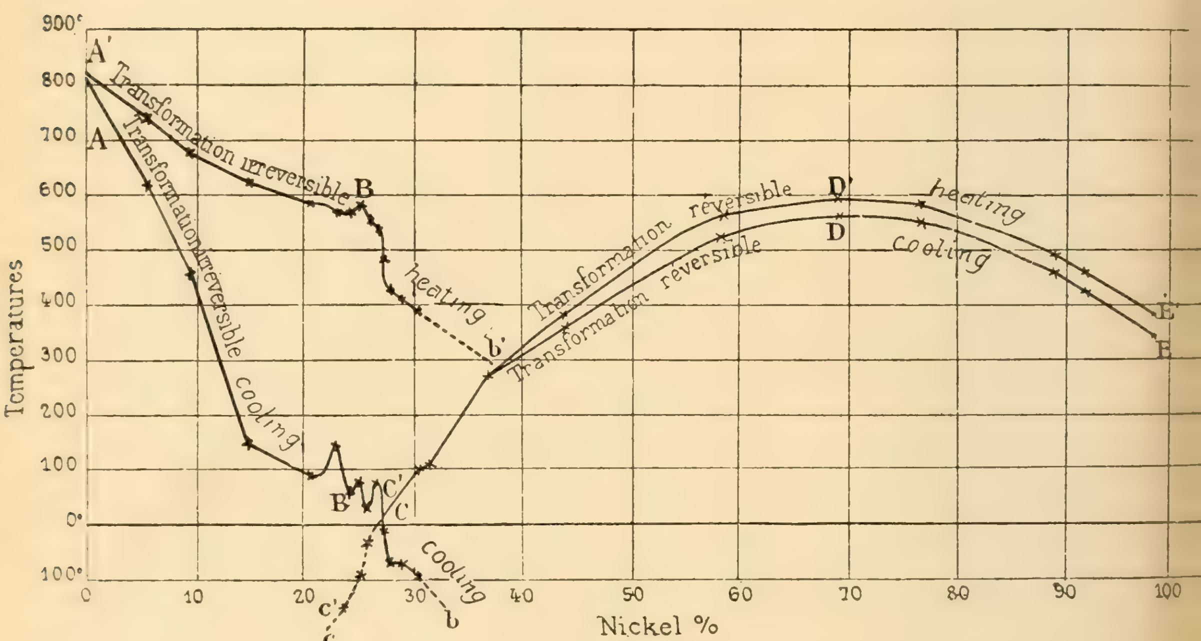

Fig. 1. Positions of the points of allotropic transformations of nickel-steels containing from 0 to 100 per cent nickel.

vious experiments yielded similar results with samples containing as much as 30.44 per cent of nickel and but a small amount of carbon and manganese.

These observations induced us to ascertain the positon of the transformation points of our samples. The results obtained are as shown in Fig 1.* This diagram is very similar to Osmond's except for steels containing from 23 to 31 per cent of nickel.

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* For a detailed description of the conduct of the experiments and of the results obtained see my paper on "Researches for Carbon and Nickel, à Hautes Teneurs," p. 50 and 55.

It will be noted that the curves of irreversible transformation no longer stop at 25 per cent of nickel, but extend to 30.44 per cent, and it might be inferred that their extension would have been still greater if we had used a more sudden cooling, as for instance, in liquid hydrogen. The irreversible transformation of steel containing 30.44 per cent nickel is undoubtedly the same as that of steel containing less than 25 per cent of nickel, as we have on the one end a transformation point on heating at 375° — before cooling a reversible point of transformation occurs at 90° — and on the other end a modification of the mechanical properties, elastic limit, tensile strength and elongation which are characteristic of this transformation. The following results were obtained in testing two samples from the same steel bar containing 30.44 per cent nickel, one normally cooled and the other cooled in liquid air:

	Elastic Limit	Tensile Strength	Elongation	Reduction
Normally cooled.........	35 K	54.5 K	30 per cent	70.7 per cent
Cooled in liquid air.....	87 K	98.4 K	11.2 per cent	50 per cent

The extension of the curve of the reversible transformation is marked on the diagram as a dotted line because it was not directly ascertained in the case of steel containing little carbon, the points plotted on the diagram having been obtained with highly carburized steel. Must we not conclude, however, that they must exist in the same position whether there is or not any carbon, since this element has no influence on the position of the points of reversible transformation. In the case of steel containing little carbon the irreversible transformation takes place first when cooling and hides the reversible transformation; an addition of carbon reveals it because it lowers the point of irreversible transformation.

The Irreversible Transformation and the Reversible Transformation are Distinct Phenomena. — It seems certain that the curves representing these two transformations cross each other and extend far beyond their meeting point. If some doubt existed on this point, it is at least certain that these two transformations are not due to a change of speed of the allotropic transformation, but are two distinct phenomena independent of each other, which may be studied separately, and this is what I have done, taking first the irreversible transformation.

II — Study of the Irreversible Transformation

Principal Manifestations of This Transformation. — The manifestations which are characteristic of the irreversible transformation are on the one hand deep modifications of the physical properties of steel which take place when the temperature increases above the transformation point or is lowered below these points and on the other hand gaps, often very considerable, between the transformation point of heating and the point on cooling. I shall study first the principal modifications of the physical properties.

(a) modification of the physical properties

Magnetism. — It is especially in observing the modifications of the magnetic condition that we have followed the course of the transformation, because no observation is easier to make than that which deals with the appearance or disappearance of magnetism, especially at temperatures below 200°, since it is sufficient to place a magnet near the steel after having heated or cooled it in a bath.

It is easy to distinguish between the magnetism produced by the irreversible transformation and that due to the reversible transformation, since in the first case it disappears only after a considerable increase of temperature, while in the latter case it disappears as soon as the temperature is slightly increased. The perfect coincidence between the appearance of magnetism during cooling and the modification of the other physical properties of steel in the case of the irreversible transformation is especially noticeable with steels which are non-magnetic, at the ordinary temperature and which undergo the transformations when the temperature is lowered below 0°.

Modification of the Mechanical Properties. — The irreversible transformation is of especial interest to the metallurgist because of its important resulting modifications of the mechanical properties, such as the elastic limit, the tensile strength, the elongation and brittleness. Let us subject to the tensile tests two samples of nickel-steel, the first one containing 16 per cent nickel and having undergone the transformation, the second containing 28 per cent nickel and not transformed, or better still containing enough carbon, chromium and manganese to lower its transforma-

tion considerably below the ordinary temperature. The composition of these samples was as follows

	Carbon	Manganese	Chromium	Nickel
Magnetic steel..................	0.16	0.13	...	15.92
Non-magnetic steel............	0.53	0.83	3.02	16.05

Let us ascertain how these steels behave when subjected to a tensile test. The distortion of the first one is confined to a small portion where rupture will take place. The remainder of the test bar retains its original luster as may be seen from Fig. 2. The second bar undergoes first a distortion over the whole length and is followed by a local distortion preceding rupture. We must,

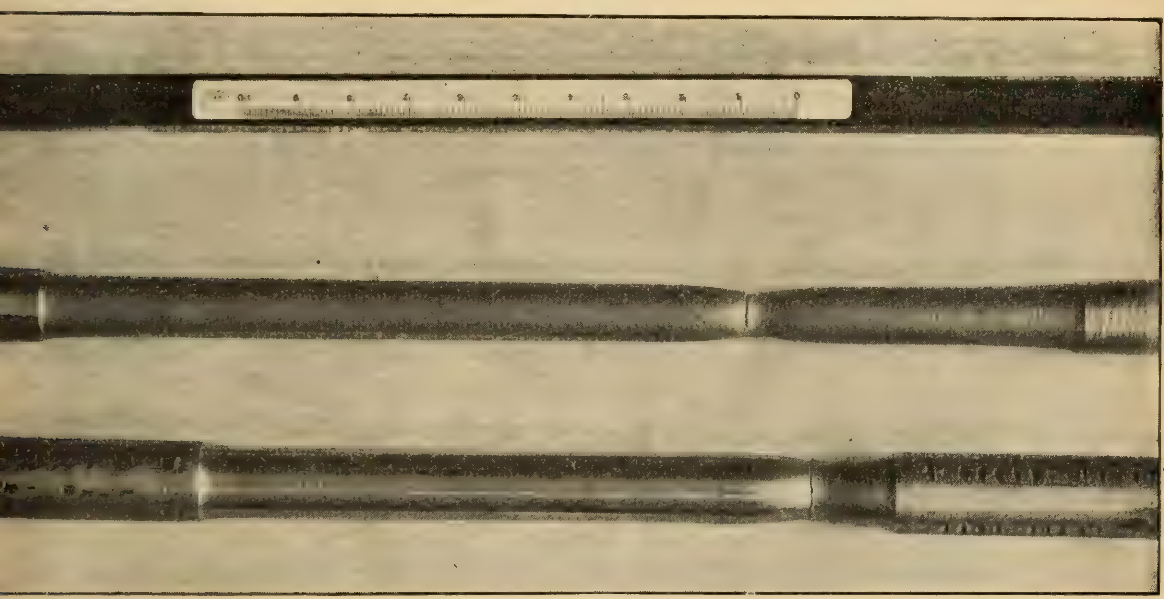


Fig. 2 Photograph of two test-bars of nickel-steel containing 16 per cent of nickel, one of them magnetic, the other non-magnetic.

therefore, distinguish in the latter steel two phases in its distortion, while only the second of these distortions was observed in the case of the first sample. Below are the results obtained in testing these samples at the steel works of Imphy:

	Elastic Limit	Tensile Strength	Elongation	Reduction
Magnetic steel...........	76.2 K	89.2 K	19 per cent	54.5 per cent
Non-magnetic steel......	32.8 K	77.5 K	73 per cent	68.0 per cent

It will be seen that the elastic limit of the first steel approaches its strength, while the elastic limit of the second sample is far

below its strength. In the first case it represents 87 per cent of the strength, in the second only 42 per cent. It is why, in the testing of the latter sample, the final distortion is preceded by a preliminary distortion during which the elastic limit is raised. The portion of the bar which was first distorted ceases for a while to stretch because its elastic limit has been raised and it is now another portion which in turn is distorted, and so on over the old length of the bar until the elastic limit has been in this way raised in every portion. This period of distortion corresponds to a regular cold working of the steel, such as takes place in wire drawing and it is only after this cold working is completed that a sample breaks under conditions almost identical to those producing the fracture of the first steel. This cold work may be applied to the bar before subjecting it to the tensile test by drawing it through a die, in which case the first phase of the distortion disappears. We give below some results obtained in testing steel bars cut from the same piece of steel containing 28 per cent of nickel before and after having undergone this wire-drawing operation.

	Elastic Limit	Tensile Strength	Elongation	Reduction
Before cold working.....	32.1 K	57.8 K	34 per cent	55 per cent
After cold working......	92.1 K	92.1 K	11.7 per cent	63.5 per cent

By passing the steel through a die it has lost its property of undergoing the preliminary distortion. It breaks in conditions similar to that of the steel containing 16 per cent of nickel, which had been made to undergo the irreversible transformation. We must infer from these results that this transformation and cold working are identical phenomena from the point of view of the modification of the mechanical properties. The following results show that these effects are not only similar, but indeed identical. Four samples were cut from a piece of non-magnetic steel containing 23 per cent of nickel, 0.5 of chromium, which had been quenched and then subjected to the treatments indicated.

Treatment	Elastic Limit	Tensile Strength	Elongation	Reduction
Untreated	30.9 K	71.8 K	35 per cent	41.5 per cent
Cooled to 78°...........	102.6 K	137 K	20.3 per cent	21.5 per cent
Cold worked............	129.5 K	139 K	13.3 per cent	28.2 per cent
Cold worked and cooled..	141.5 K	149 K	12.7 per cent	32.1 per cent

The second bar showed after cooling a very great increase of its elastic limit, from 30.9 to 102.6 K and the third bar showed after cold working a similar increase, bringing its elastic limit to 129.5 K, that is, respectively, increases of 71.7 and 98.6 K. Both treatments, however, when combined, only result in an increase of 110.6, from which we infer that their effects are not cumulative; they only complete each other. We must admit that the irreversible allotropic transformation produces an effect similar to cold working.

Rapid Modification of Volume. — One of the most characteristic manifestations of the irreversible transformation, whether it occurs in a non-magnetic steel or in a steel already magnetic, because of its reversible transformation, consists in a rapid modification of the volume of the steel which takes place inversely to that resulting from the general laws of dilatation of substances through the application of heat, that is to say, an increase of

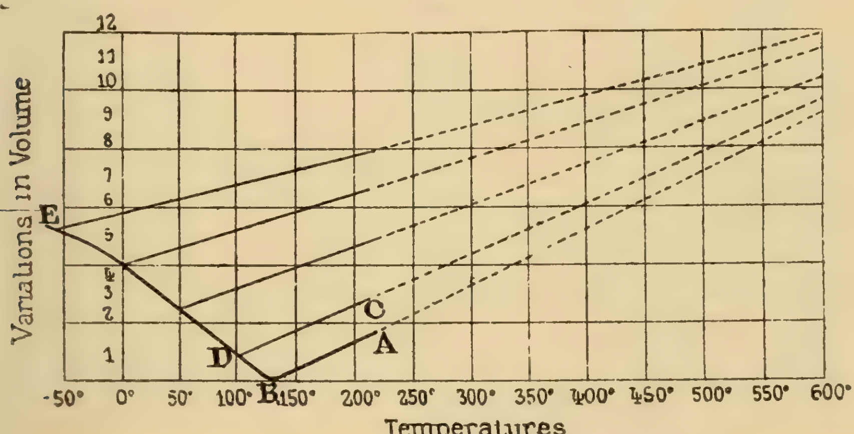


Fig. 3.

volume during cooling. The cold working effect which I have just mentioned as one of the manifestations of this transformation takes place at the same time. Is it not, then, a result of this last phenomenon? An increase in the volume of the molecules under the influence of the irreversible transformation would explain why, after it has taken place, the molecules of steel seem to have lost the faculty of sliding over each other as if they were subjected to a considerable pressure.

Let us imagine that when nickel is added progressively to pure iron, the molecules of nickel arrange themselves between the iron molecules and exert upon these a pressure which is the

greater, the more nickel present, thus causing a cold working effect of increasing intensity, which in turn results in an increase of the elastic limit. This period of increasing internal tension, however, is succeeded by a second beginning when the nickel content reaches 20 per cent, when the iron changes progressively its allotropic state; the volume of the molecules decreases, the pressure to which they are subjected diminishes and ductility reappears.

Mr. Guillaume has studied this increase of volume under the influence of cooling in an important experiment, the results of which are shown in the diagram of Fig. 3. The steel used contained 15 per cent of nickel. It will be seen that the falling of the temperature below the point of transformation on cooling, which is located at about 130°, increases the volume instead of decreasing it. The course of the transformation should be especially noted; according to Guillaume it undergoes some temporary stops; the temperature may be lowered some 15° without producing any contraction, which then takes place abruptly, and in a few seconds the volume increases by the same quantity as if the increase had taken place regularly. This also is similar to the effect of cold working, for it is easy to ascertain on the diagrams of tensile and compressive tests of nickel-steel which have undergone the irreversible transformation that the increase of the elastic limit takes place by leaps corresponding to the horizontal portions of the curves, and which indicate the elastic limits of a series of different molecular states. We must conclude from these observations that the irreversible transformation has, like cold working, the characteristics of a rubbing action. The sliding of the molecules over each other appears to take place with greater difficulty at the start and with several stops produced, so to speak, by gripping.

Modification of the Structure. — Metallographical methods add interesting information to this study. Mr. Guillaume cooled in liquid air a sample of steel containing 30.44 per cent of nickel with a polished surface, thereby producing its partial transformation, and he noted that the portions which were transformed stood in relief in the shape of small crystals, which Mr. Osmond found to be martensite. We again infer from this that the transformed portions exert a pressure upon the others, or, in other words, produce a cold working effect.

The rapid modification of volume and the modification of the magnetic properties appear to be closely united. A perfect agreement exists, moreover, between the modifications of the structure and the magnetic properties. Mr. Guillet, following the experiments of Mr. Osmond, has just shown it by numerous observations. The martensite structure of steels which have undergone the irreversible transformation corresponds to high elastic limits while the polyhedric structure of steels, which have not undergone the transformation corresponds to low limits of elasticity.

Thermal Phenomena. — The irreversible transformation takes place with a notable evolution of heat, which is an indication of considerable internal mechanical work. This manifestation of the transformation also has a tendency to impart to this internal work the character of a molecular rubbing action. Although considerable, this evolution of heat is less apparent in the case of steels containing much nickel than in pure iron, because it takes place less suddenly. The transformation occurs progressively over a range of temperature of at least 50°, when the steel contains 15 per cent or more nickel.

Other Modifications of the Properties Corresponding to the Irreversible Transformation. — I shall only mention here the modifications of the coefficient of expansion, of conductivity both for heat and electricity, of specifc heat, etc. It is enough to show that this transformation modifies deeply most of the physical properties of nickel-steel.

(b) GAPS BETWEEN THE POSITIONS OF POINTS OF IRREVERSIBLE TRANSFORMATION

Relation Between the Increase of the Gap Existing Between the Transformation Points on Heating and on Cooling, and the Intensity of the Modifications of the Physical Properties. — The diagram of Fig. 1 shows that a gap between both points of transformation increases as the nickel increases until 15 per cent of nickel is present, when the gap no longer increases materially.

It has been shown, especially through the study of the mechanical properties of nickel-steel, that the modification produced by the irreversible transformation increases in intensity precisely up to a nickel content of 15 per cent, in other words, the gap is the greater the more intense the transformation. It was, there-

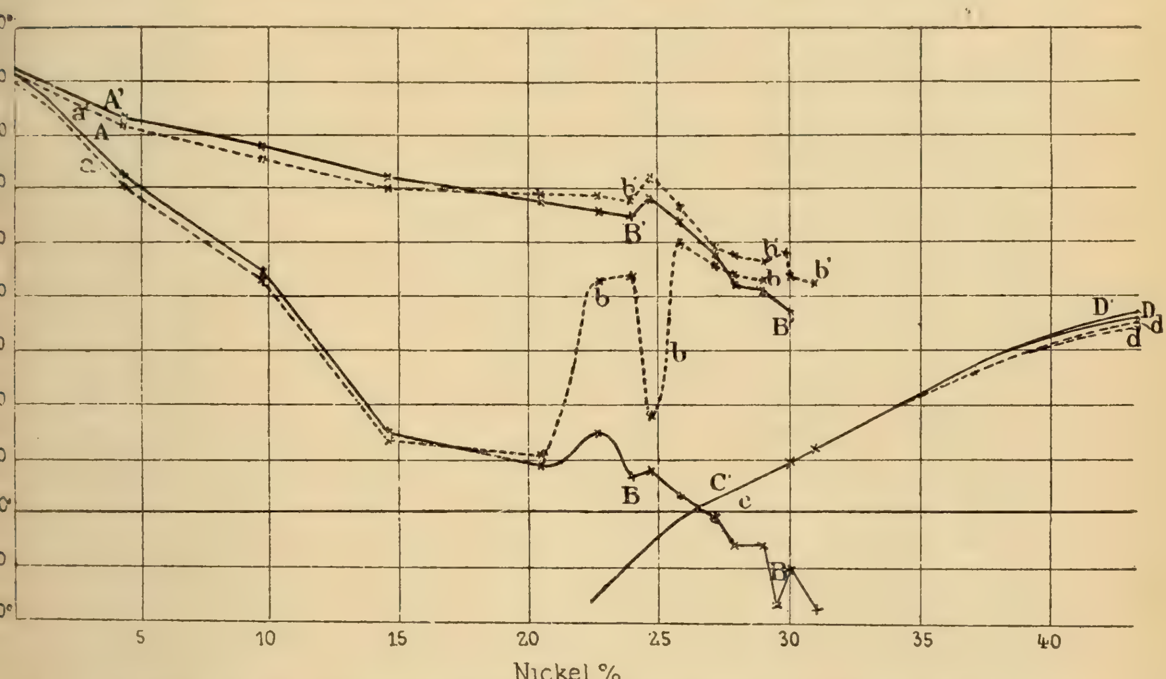
fore, interesting to study the reasons which might cause this variation.

Rise of the Transformation Point on Cooling Under the Influence of Physical Treatments. — The influence of quenching upon the position of the transformation point on cooling was revealed by the following observation: While trying to cause the transformation of some non-magnetic steels through cooling we were led to observe that some of them which cannot be transformed in a bath of solid carbonic acid, that is to say, at — 78°, underwent the transformation at this temperature, if the cooling was preceded by quenching in cold water after heating to 800° or 900°, from which it follows that quenching raises the transformation point on cooling of these steels.

The magnitude of this rise, which varies with the intensity of the quenching, may be ascertained within some 10°. Our experiments have also shown that a similar rise may be obtained by subjecting these steels to cold working or to a reheating to 800 or 900°. The position of the transformation point on heating is not modified to the same extent and this results in decreasing the gap between the two points. We infer from the above that these treatments have a tendency to destroy the hysteresis of temperature, a kind of molecular rubbing which is the cause of the delay of the transformation on cooling and having a tendency, therefore, to bring back the transformation point on cooling to a position in the vicinity of that of the transformation point on heating. In other words, the gap between these two points varies with the state of molecular equilibrium of the steel. It depends not only upon its composition, but also upon its physical condition.

Position of the Points to Magnetic Transformation of Steels Which Have Been Subjected to Physical Treatments. — Fig. 1, which shows the positions of the points of magnetic transformation of nickel-steels after forging, does not indicate that of steels which have been subjected to other physical treatments. We were led by these considerations to ascertain the transformation points of the samples of steel which we had especially used in our first experiments after having subjected them to quenching, cold working and annealing. The diagram of Fig. 4 sums up the results obtained with steels first quenched and then cold-worked so as to raise as much as possible the transformation points. The black lines are the reproduction of those of Fig. 1, while the dotted

curves indicate the results of these new experiments. This diagram shows that in the case of steel containing more than 21 per cent of nickel, a rise of the transformation point on cooling occurs which may be so considerable as to bring this point very close to the transformation point on heating, the latter being itself slightly raised. The effect of hysteresis is here almost entirely eliminated, as far as the magnetic transformation is concerned. The false molecular equilibrium due to hysteresis is replaced by



ig. 4. Positions of the points of transformation of nickel-steel containing from 0 to 45 per cent nickel before and after quenching and cold working.

B B. Curve of irreversible transformation on cooling, before quenching and cold working.
b b. Curve of irreversible transformation on cooling, after quenching and cold working.
' B' B'. Curve of irreversible transformation on heating, before quenching and cold working.
b' b'. Curve of irreversible transformation on heating, after quenching and cold working.
D. Curve of reversible transformation on cooling, before quenching and cold working.
d. Curve of reversible transformation on cooling, after quenching and cold working.
' D'. Curve of reversible transformation on heating, before quenching and cold working.
d'. Curve of reversible transformation on heating, after quenching and cold working.

an equilibrium almost normal under the influence of cold working and of quenching.

When the steel contains between 15 and 21 per cent of nickel cold working produces no longer any effect. This might have been anticipated because these steels which have undergone the

irreversible transformation in its full intensity are, so to speak, cold worked in advance. Below 15 per cent of nickel cold working produces only a slight fall of the transformation point on heating and on cooling.

The points of magnetic transformation of steels which have been subjected to physical treatment coincide no longer with the transformation points related to the modifications of the magnetic properties. The running together of the points of magnetic transformation, which is made apparent by our determinations, is not an indication of a general rise of the temperatures at which all manifestations of the irreversible transformation take place, especially the modification of the magnetic properties. We made some additional tests of two non-magnetic nickel-steels containing some chromium and of the following composition: Carbon 0.8 per cent, chromium 2.5 per cent, nickel 23 per cent. One of them was first subjected to a reheating for five hours between 800° and 900°. The following results were obtained:

	Elastic Limit	Tensile Strength	Elongation	Reduction
Before reheating.........	50.1 K	83 K	41 per cent	60 per cent
After reheating..........	31.8 K	76 K	49 per cent	67 per cent

The effect was to lower considerably the elastic limit, a result which is exactly opposite to the one produced by the irreversible transformation. This steel becomes magnetic at the ordinary temperature, while it remains non-magnetic when in liquid air at — 188° before having been heated in this condition.

On the other hand, Messrs. Charpy and Grenet have ascertained that no notable modification of the coefficient of expansion takes place at the temperature where magnetism occurs on cooling in the case of nickel-steels after cold working and this modification is one of the important manifestations of the irreversible transformation. We must infer from this that the appearance of magnetism occurs before the other characteristic modifications of the irreversible transformation, when the steel is reheated or cold worked. The same is true of quenched steel. The effect produced by these treatments which I ascribed to a destruction of false molecular equilibrium, recalls the return to a normal equilibrium after surfusion or sursaturation; the analogy, however, is not very close. Under the influence of physical treatments the steel passes through

a series of transitory molecular states, differing from that corresponding to the maximum hysteresis, although it cannot reach the state which corresponds to a complete absence of hysteresis. It is seen then that nickel-steels may exist under different states of molecular equilibrium and under different allotropic conditions, each one of these conditions possessing special properties.

Theory of the Irreversible Transformation. — We must distinguish in the irreversible phenomenon on the one hand an allotropic transformation and on the other a molecular transformation, both transformations reacting upon each other. The allotropic transformation which, according to Mr. Osmond, corresponds to the transformation of the iron contained in the steel is itself a complex phenômenon. For instance, during cooling we must distinguish between the passage of a portion of *Gamma* iron to the magnetic *Alpha* iron, and the passage of another portion of *Gamma* iron to the *Beta*, a condition of the iron of which the most important characteristics from our point of view consist in a condition resembling that of cold worked steel under the action of an internal tension. In the case of a non-magnetic steel at the ordinary temperature, which is transformed by cooling without having been subjected to any treatment but forging, all the transformations take place simultaneously, a perfect coincidence existing between the appearance of magnetism, of *Alpha* iron and a rise of the elastic limit. Such is not the case, however, when this steel has been cold worked or quenched or reheated. The magnetic transformation takes place then before the others. It seems evident, therefore, that the transformation of *Gamma* into *Alpha* iron takes place independently of the transformation of that iron into *Beta* iron.

III — Study of the Reversible Transformation

Characteristic Manifestations of this Transformation. — Although having no action upon the magnetic properties and producing no rapid modification of volume nor modification of structure as the irreversible transformation does, the reversible transformation corresponds, nevertheless, to important modifications of the physical properties of steel. The most important are the following:

Magnetism. — Magnetism appears on cooling at a temperature very close to that at which it disappears on heating. Its in-

tensity increases progressively, at least with less than 50 per cent of nickel, as the temperature decreases or, what is nearly the same, as the nickel content increases. Mr. E. Dumont gave on this matter very interesting and precise indications making it possible to follow the progress of the transformation.

Dilation. — The coefficient of expansion at ordinary temperature decreases as the intensity of magnetism increases and this decrease is very considerable with certain steels, the expansion being nil with a nickel content of 36 per cent. Mr. Guillaume, who discovered this remarkable property, studied carefully the laws which control the expansion of nickel-steels. He has shown that the action of the reversible transformation upon the expansion is much more important than that of the irreversible transformation.

Elasticity. — I shall only call attention to a very great variation of the modulus of elasticity similar to that of the coefficient of expansion, a property which is utilized in clock-making and which is a consequent of the reversible transformation.

Effect of Physical Treatments. — Cold working and quenching have apparently no effect upon the position of the points of reversible transformations, but such is not the case with prolonged reheating. We have recently observed at the steel works of Imphy that the points of reversible transformation of steels containing from 29 to 50 per cent of nickel, reheated to 800° or 900° for one hour at least, are raised more and more as the nickel-content decreases. They occur at about 600°, which, with a nickel content of 29 per cent, represents a rise of more than 500°. This rise is not accompanied by an increase of the elastic limit, which, on the contrary, is considerably decreased. This was shown by the tensile test of a piece of steel containing 36 per cent nickel.

Theory of Reversible Transformation. — The reversible transformation appears to be exclusively allotropic, producing apparently no molecular modification. From diagram 1, it is seen that the reversible transformation is connected with the allotropic transformation of pure nickel exactly as the irreversible transformation is connected with that of pure iron. This consideration led me at first to look upon the reversible transformation as being the transformation of the nickel contained in the steel. The phenomenon, however, is more complex, for we must admit that a portion at least of the iron of the steel is transformed at

the same time. Mr. Osmond was the first to show this and Mr. Guillaume has recently confirmed it by many arguments. Mr. Guillaume, accepting Mr. Osmond's conclusion, infers that the absence of expansion in a steel containing 36 per cent of nickel results from the positive expansion of nickel which follows the general law of the expansion of bodies, and of a negative expansion of the iron which results from a reversible allotropic transformation of a part of the iron contained in the steel and which takes place at the same time with the transformation of the nickel. It might be objected that a transformation of the iron should be accompanied by some modifications of the physical and mechanical properties which are characteristic of the irreversible transformation while such modifications are not produced, however, by the reversible transformation. I have, however, precisely shown that the appearance of magnetism may not be connected with the production of other modifications of physical properties and this seems to give an answer to the objection.

On the other hand it appears difficult not to attribute a certain part to the iron in the reversible transformation seeing that prolonged reheating raises the points of reversible transformation, the more so the more iron in the steel.

Conclusions. — To sum up, the properties of nickel-steel may for the most part be considered as the manifestations of two distinct allotropic transformations, the irreversible transformation and the reversible transformation. Both of these transformations take place under different conditions when the physical conditions of the steel vary, that is to say, this occurrence is affected by the steel having been previously forged or quenched or reheated or cold worked. This study of molecular mechanics is a very complex one and is far from being completed.

SOME NEGLECTED DETAILS IN THE EXPERIMENAL STUDY OF ALLOYS*

By E. S. SHEPHERD

IN several recent papers devoted to the study of alloys, certain important details seem to have been neglected. We refer especially to the pyrometric and metallographic work.

If the pyrometric work is to have any value it must be not only accurate but must include all of the secondary heat changes which can be detected with the pyrometer. It is insufficient to stop with the mere determination of the freezing point. It is recent history that although the freezing point curve for the copper-tin alloys had been determined with great accuracy by Heycock and Neville, not one step was made in the solution of the problem until Roberts-Austen published his results showing the concentration limits of the inversion temperatures and eutectics. And while it is possible, and at times necessary to determine the constitution of a given alloy without the pyrometric data, it is nevertheless a time consuming and difficult task.

Tamman has pointed out that from the range of concentrations over which the inversion and eutectic temperatures extend, one may make at least a preliminary guess as to the composition of the phase separating along the freezing point curve. While his deductions are based on the *explicit assumption that no solid solutions occur,* the method is of great value in directing the course of experiments. Even for the case of solid solutions his method furnishes many valuable suggestions.

We know that little or no progress has been made in the study of any alloy until these secondary breaks in the cooling curve have been determined. We have also seen how readily in the case of bronzes, the problem was solved after these secondary breaks had been recorded. It is evident, also, that where these breaks have not been determined, the entire series of experiments must be repeated before other methods can be applied intelligently. Is it not surprising that not one of the curves published in the last year has included these essential data?

What is worse, the curves published have, in nearly all cases, been determined under conditions which insure the maximum in-

* Received June 1, 1904.

accuracy. In ordinary cryoscopic work extreme care is taken to prevent surfusion both by constant stirring and by the addition of nuclei of the phase separating. With alloys it is different. Twenty or fifty grams of alloy is melted, carefully packed in the furnace and allowed to freeze spontaneously. Since the alloy is not disturbed in any way, we have chosen the very best conditions for surfusion. In other words, we have chosen the very best conditions for *not* determining the freezing point. It is seen at once that we may have minima produced, which minima are entirely due to surfusion, and the singular thing about it is that in most of the recently published curves minima are obtained for only one composition and the neighboring compositions show no trace of secondary heat evolutions corresponding to these minima. A case in point is the freezing point curve for AlSn. A minimum was obtained at 20 per cent Al and 500°. This eutectic did not appear in any other composition, although the 228° eutectic was observed in all compositions up to 75 per cent Al, even in the composition which gave the above mentioned minimum. Here then was an apparent minimum, a drop of 50° below the true freezing point of the alloy and due entirely to surfusion. The failure of a minimum on the freezing point curve to appear as a secondary break in cooling curves of neighboring compositions calls for a most careful investigation of this supposed minimum. As a typical case, take the curve for aluminium and magnesium, Fig. 1. This is a most extraordinary curve. Although not impossible, it certainly possesses very interesting properties, if correct. The flat BC is peculiar. Ordinarily it would indicate a region for two liquid layers. But is it not more reasonable to suppose that this branch of the liquidus takes the direction AC and that BC is so steep that the freezing point could be determined only with the greatest difficulty, even if the alloy had been stirred, which it was not. One could scarcely hope to detect it with a direct reading pyrometer. Would it not lend probability to the eutectic D if the eutectic temperature along ee had been observed? It is also to be noticed that the maxima E and G, are less than 50° above the minimum F, and while the one measurement at 40 per cent Al lends probability to the existence of two maxima, the evidence is not conclusive. In fact, that minimum F lies easily within the limits of experimental error. If the eutectic temperatures at F and H had been determined for the neighboring con-

centrations there would then be no doubt as to the real nature of the curve.

The compound Al_4Mg was suggested as possible, but it is seen that there is no place for such a compound on the branch

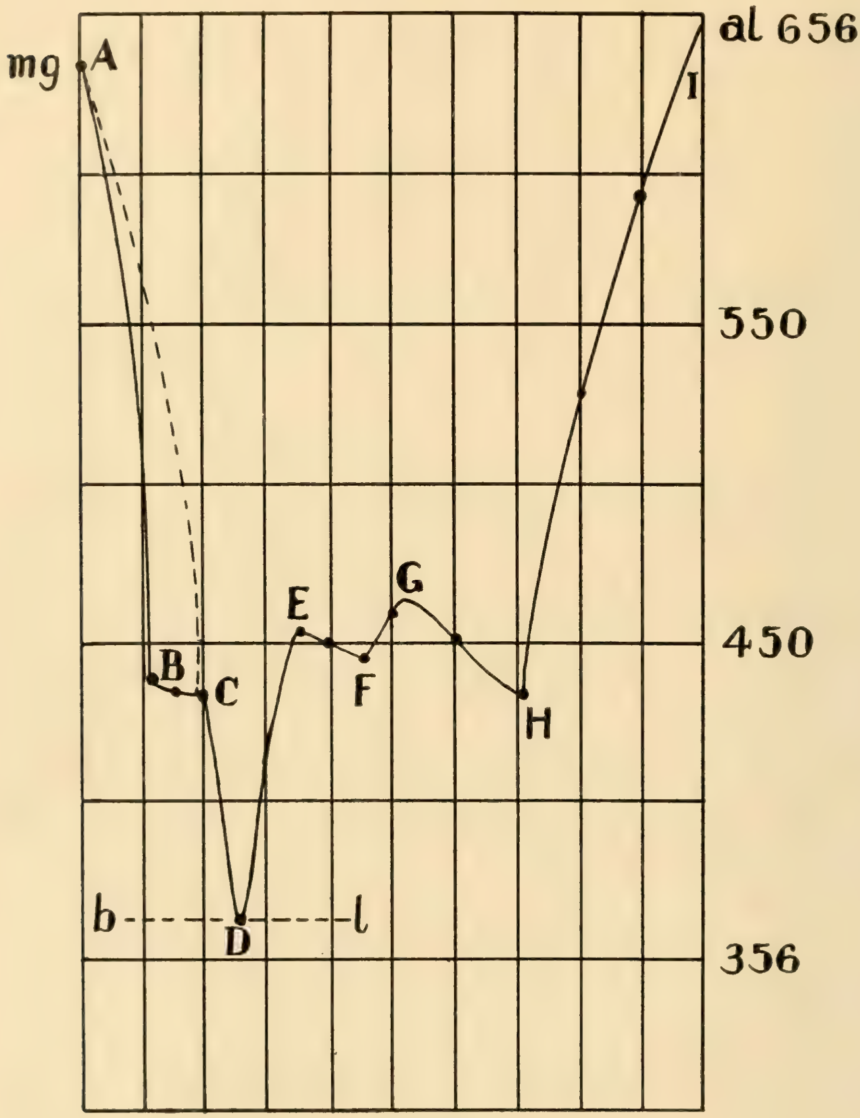


Fig. 1.

HI. If this phase exists there must be an inversion point somewhere along this branch. The fact that the 85 per cent Al alloy was found to be homogeneous would (if the pyrometric data are correct) point rather to the existence of a solid solution along HI than to a compound, though both might occur, provided an inversion point exists also. The copper magnesium curve by the same

investigator possesses the same lack of finish and the same experimental errors. Furthermore, these melting points were determined in glass or porcelain tubes. It is not impossible, therefore, that the alloys were in both cases saturated with silicon. Anderson and Lean observed that the much less energetic aluminium-tin alloys could take up as much as 11 per cent of silicon from a plumbago crucible. It is admitted that AlMg and MgCu alloys are very difficult to study, nevertheless, such negligence of experimental detail coming repeatedly from one of our best, and one of the few active experimentors in this field, seems to justify this rather extended criticism. This negligence is not, however, characteristic of this particular investigator, it vitiates nearly all of the work which has appeared within the last few years. Thus, Hiorns in an interesting and important paper on copper-arsenic alloys has frankly given the variations in the freezing points as he determined them. Variations of from 15° to 50° are the rule, averaging about 35°, and in one case a variation of 80° occurs. Of the maxima found in this curve, one is 100° and the other 50° above the temperature of the neighboring minima. If variations of 40° occur in the determination, what probability attaches to these maxima.* It is true the microscopic evidence tends to corroborate the pyrometric, but the failure to observe the essential details of freezing point determinations leaves all of the conclusions in a most unsatisfactory condition. Is it not surprising that not since the classic researches of Heycock and Neville has efficient stirring been maintained, if it has been attempted? That is synonymous with saying that there has not been a really accurate freezing point curve determined since the above-mentioned work. It is an unpleasant reflection, but unfortunately it is true.

One reason why the secondary halts in the cooling curve have been neglected is doubtless that many of the determinations have been made by reading the temperatures directly and plotting them against the time. There is no occasion for such a crude method; it never gives accurate results. If one has the thermocouple, a recording pyrometer can be constructed at a cost of not over twenty dollars *including* the galvanometer, and for five

* Compare with the determination by Heycock and Neville, who duplicated all of their work and obtained results agreeing to within one degree and often to within two-tenths of a degree.

dollars or less if a galvanometer is available. By substituting bromide paper for glass plates the cost of running can be made very much less, though the accuracy is slightly diminished. There is a tradition, descended doubtless from the work on iron and steel, that a few grams of alloy is plenty for a freezing point determination. This might be true if the couple could be placed directly in the alloy as it is in the steel blocks. But where the couple is separated by a wad of asbestos or, as is the present custom, by a porcelain jacket, only the most violent evolutions

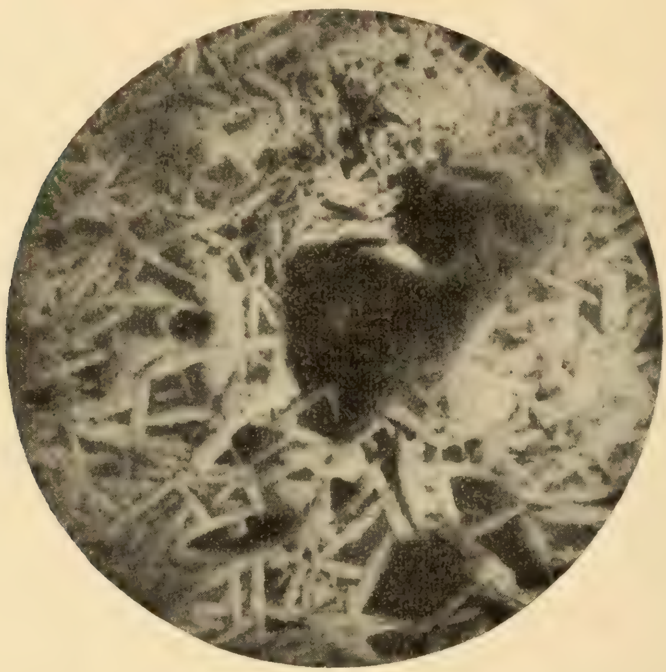


Photo 1. 35 per cent Cu, 65 per cent Sn; 180 diameters.

of heat will be recorded. Furthermore, efficient stirring can only be maintained with relatively large amounts of alloy, 100 to 300 grams. In special cases and if special care is taken, smaller amounts can be used. But where smaller amounts are used, we should be given some assurance that the necessary effort has been made to prevent surfusion.

In metallography there is still little evidence of the legitimate fruits of Heycock and Neville's "Effect of Chilling Copper-Tin Alloys." In the paper giving a systematic examination of copper arsenic alloys Hiorns has entirely neglected this phase of the subject. The slowly cooled specimens are examined and it has

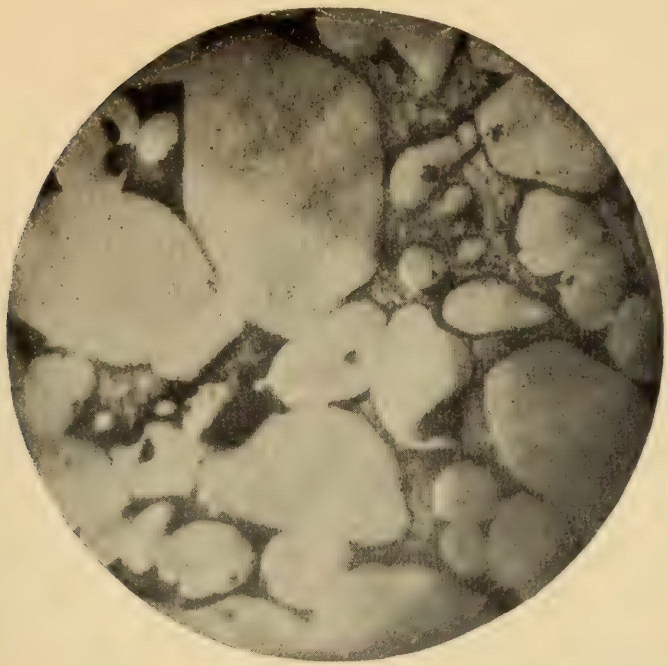


Photo 2. 35 per cent Cu, 65 per cent Sn; 180 diameters.

Photo 3. 35 per cent Cu, 65 per cent Sn; 180 diameters.

been tacitly assumed that equilibrium has been reached. There is little reason to suppose that it has been. Compare the chill cast and annealed bronze of 35 per cent copper with the slowly cooled bronze (photos. 1, 2 and 3). In photo. 3 the crystals of Cu_3Sn have been so large that even on slow cooling they could not change over into Cu_4Sn_3, the staple phase. In fact, " soaking " for three weeks at 232° is insufficient, although it is easy to show that these large crystals are instable. While in the case of the chill cast alloy equilibrium has been readily attained. It is obvious that a chill cast alloy will consist of smaller crystals and be more uniform in composition, so that on annealing, equilibrium will be more readily attained by diffusion in the solid metal. By suitable casting and annealing at the temperatures indicated by the pyrometric data, many compounds may be obtained pure and the limits of solid solutions determined for any given temperature.

Heycock and Neville have long since pointed out the difference between quenched, annealed and slowly cooled specimens of bronze. They were able to determine some otherwise unsuspected phases as a result of such examinations. In this case they had the pyrometric data as a guide. In many cases, however, the change from one phase to another is too slow to affect the cooling curve. Take, for instance, the brass containing 50 per cent Cu. If annealed at 800° and quenched it is a homogeneous solid solution. This structure is retained even on fairly slow cooling. Photo. 4 of a chill cast brass shows the incipient breaking down of the *Beta* crystals. If annealed and quenched at 800° a homogeneous structure results. Annealed below 700° the *Beta* solid solution, which is the only constituent at 800°, has broken down with the exudations of *Gamma* crystals (photo. 5). In a 66 per cent Cu brass the alloy annealed at 500° is homogeneous *Alpha* solid solution. If annealed at 800° some *Beta* crystals are exuded and are seen between the masses of *Alpha* (photo 6). This change, while reversible, is too slow to be recorded by the pyrometer. The case cited is chosen merely because it emphasizes the point made by Osmond in the May number of *The Iron and Steel Magazine*. He there pointed out that the solubility of one metal in another, as solid solution, might vary with temperature. This is well known, for the case of fused salts and the solubility curves have been carefully studied. With alloys, even our best authorities seem content to stop their investigations with the liquidus, leaving the changes

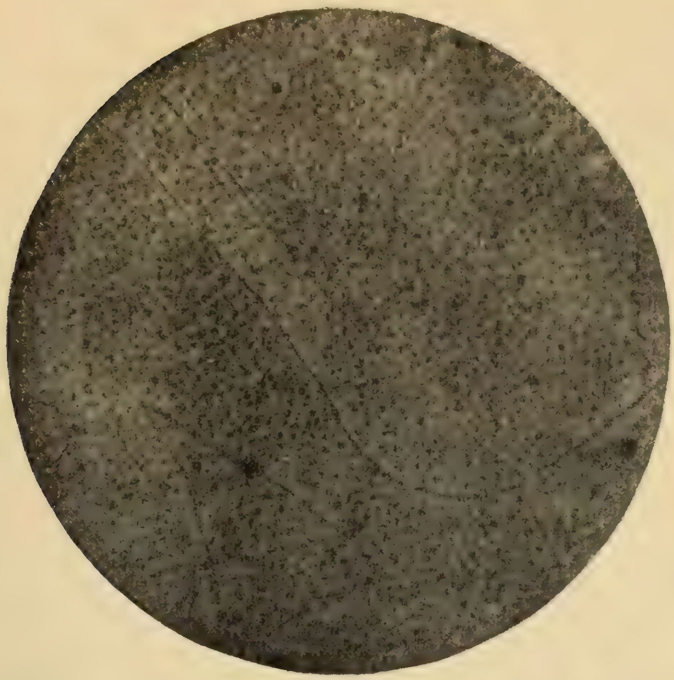


Photo 4. 50 per cent Cu, 50 per cent Sn; 180 diameters.

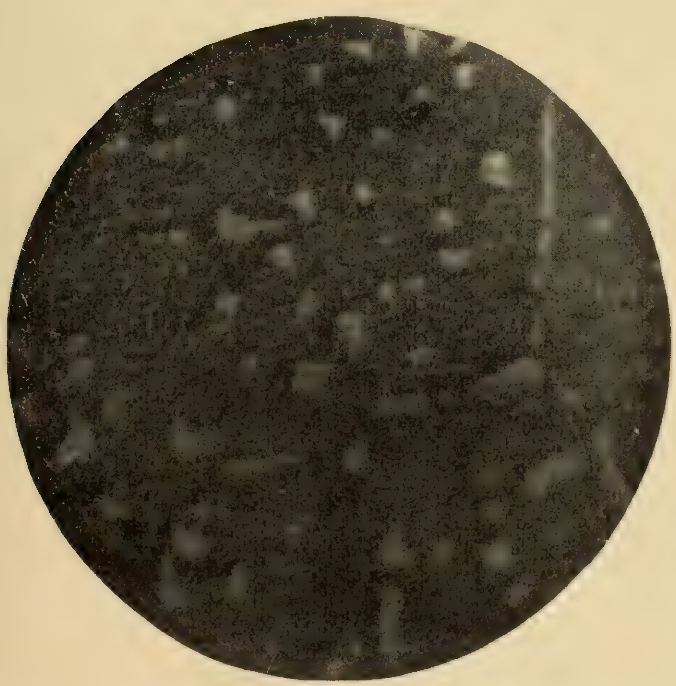


Photo 5. 50 per cent Cu, 50 per cent Sn; 180 diameters.

in the solid phase to shift for themselves. It would seem that the only rational way to study any alloy microscopically is to make a careful examination of a series of annealed specimens quenched from selected temperatures, using the pyrometric data as a guide. This method has been used in but two of the many investigations which have appeared. It seems a great pity to have a diligent worker devote six months or a year to the study of some series of alloys, only to reach indifferent conclusions in the end.

Another much neglected point is that of the density of the alloys studied. Since we know what the equilibrium conditions

Photo 6. 66 per cent Cu, 34 per cent Sn; 180 diameters.

are, it would certainly pay to take the density of the properly annealed alloys. It is but little more trouble when a series is being studied by other methods and fully repays the effort. It will surprise some to be reminded that there are no published data on the density of silver copper alloys since the work of Karmarsch in 1848, and a glance at his data when plotted as specific volumes shows that the ingots used were evidently filled with gas bubbles. If, as Osmond states, silver and copper form solid solutions to the extent of a few tenths of a per cent, the specific volume curve, while it need not, will probably coincide with the curve as calcu-

iated from the densities of the two metals. If it does not, it must, at least, be a straight line between the limits of these solid solutions. According to the best data now available the experimental curve is a crescent lying slightly above the theoretical curve. The observed values approaching more nearly to the theoretical in the case of the low melting alloys which would dissolve less gas and being further removed as the concentration approaches pure silver or pure copper.

Some measurements on the heat of formation and specific heat of alloys have appeared recently, but in no case have the investigators made certain that equilibrium had been obtained in the specimens examined. Consequently the work is useful only as showing how many careful measurements have been wasted on perfectly undefined material.

In this paper we have attempted to point out several experimental details which have been neglected in some current researches, in the hope that, in so far as the criticisms are just, they may enable us to get at the facts with less waste of patient labor.

THE KENNEDY MIXER FOR HOT METAL*

THE chilling of metal and the forming of skulls in the steelworks mixers into which hot metal is delivered from the blast-furnace has been entirely overcome by the new spherical mixer designed and built by Julian Kennedy, mechanical engineer, of Pittsburg. Two of these mixers have been installed in the South Chicago works of the Illinois Steel Co., and two at the Newburg plant of the American Steel & Wire Co. In most of the mixers in use the splashing of the metal has the tendency to form skulls, which are costly to remove. To overcome this and other difficulties the Kennedy mixer was designed. Fig. 1 is a side elevation of the mixer, the charging ladle and the cover-operating mechanism. The spherical mixer is provided with parallel circular tracks or flanges on or near its bottom, one on each side, on which it can be rolled for the purpose of bringing its discharging spout in the proper pouring position. By making

* "The Iron Trade Review," April 28, 1904.

the mixer spherical its strength is greatly increased and a minimum of material is used in its construction. The charging hopper is another novel feature, the molten metal being poured from above and delivered substantially in the middle of the pool of metal the mixer contains. By this method the splashing of the metal is obviated as far as possible and a fruitful source of skulling is

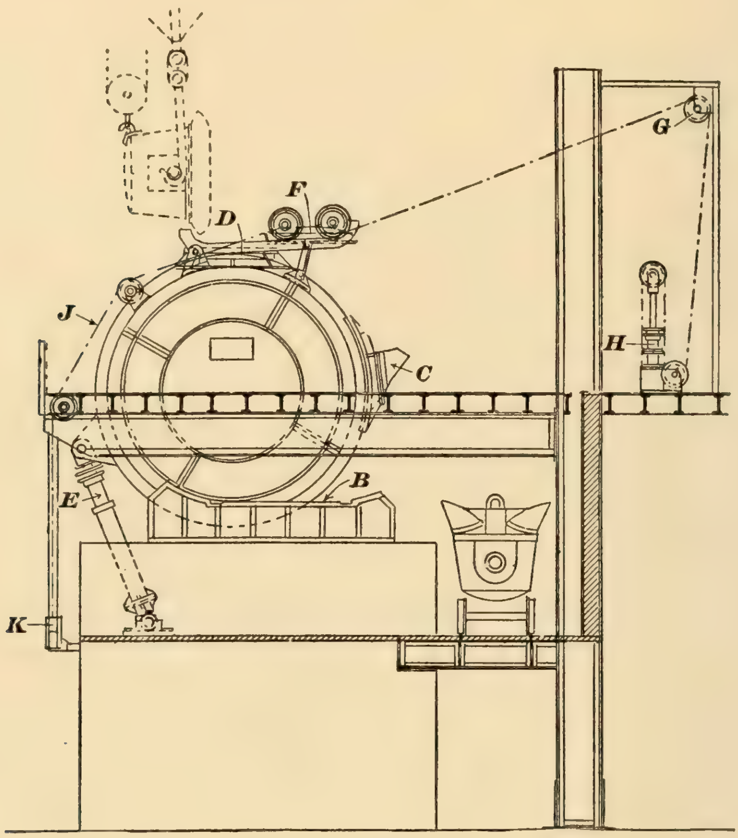


Fig. 1. Kennedy Mixer for Hot Metal.

prevented. The metal, when thus poured, also mixes more readily with the molten pool of metal and provides a more uniform material for the converters.

Fig. 2 shows the construction of the mixer — an exterior metal shell and an interior refractory lining. The exterior shell is made of plates in sections, stamped into the required spherical form, and on each of the sides there is an annular band A of cast steel, made in four united sections, although it can readily be made in a single piece. These annular bands not only serve as splices for holding the metal plates of the shell together, but

their lower sections constitute rockers or rollers which rest upon the support or rolling surfaces B on which the mixer is tipped. This construction is cheap, as only the lower sections of the bands have to be machined and the others can be used as they are cast. The pouring spout is indicated by C, while D is the charging opening in the top of the mixer, which when the mixer is in the normal position, as shown in Fig. 1, is directly above the central portion of the metal pool. For the purpose of rolling and tipping the mixer a cylinder or motor E is used, which is pivotally connected to the vessel, as shown in Fig. 2, and which on being actuated causes the mixer to roll on the surfaces B. Relatively little

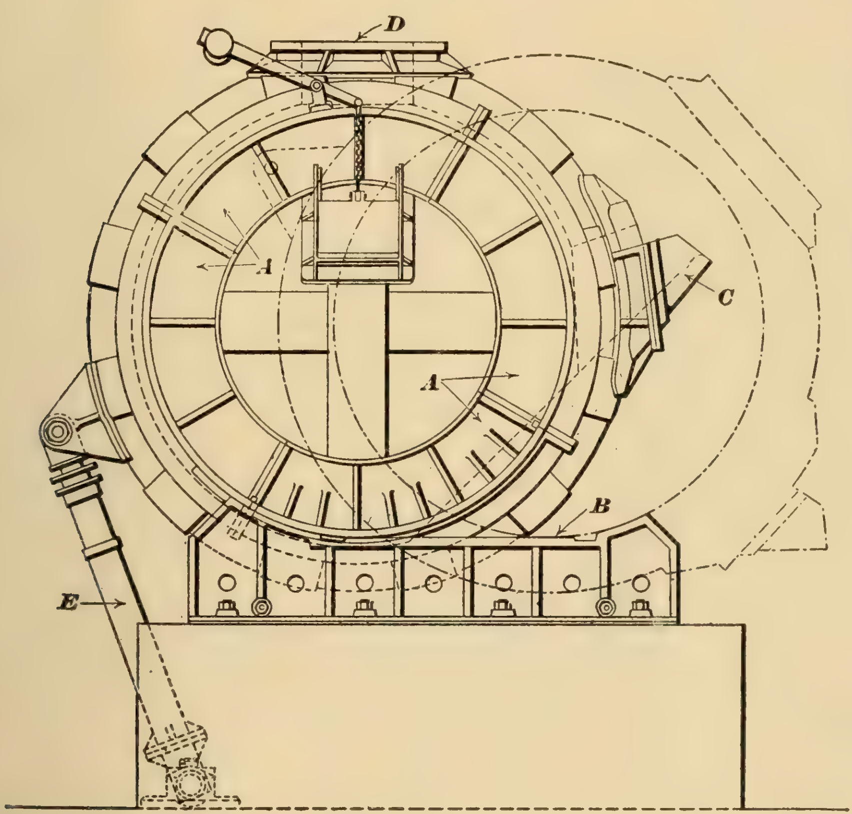


Fig. 2. Kennedy Mixer for Hot Metal.

power is required for actuating this cylinder. The charging opening has a cover indicated by F mounted upon tracks, which are fixed to the top of the mixer. It is operated by a chain, passing over a pulley G, and connected with a hydraulic cylinder H. At the rear end of the cover is another chain J, which passes over a pulley on the mixer and another pulley on a stationary support

which is provided with a counterweight K. When the mixer is to be charged with metal from the ladle, the cylinder H is operated, thereby drawing on the chain and moving the cover on its track away from the charging opening. When the water is exhausted from the cylinder H the counterweight K restores the lid to its position over the hopper, and during the tilting of the vessel the counterweight will hold the lid in place in every position of the mixer. By reason of the spherical shape the mixer is heated uniformly by the molten metal which it contains. There are no corners for the lodgment of skulls and the heat of the metal is preserved in the most effective way. Fig. 3 is a front view, one-half being shown in vertical central section.

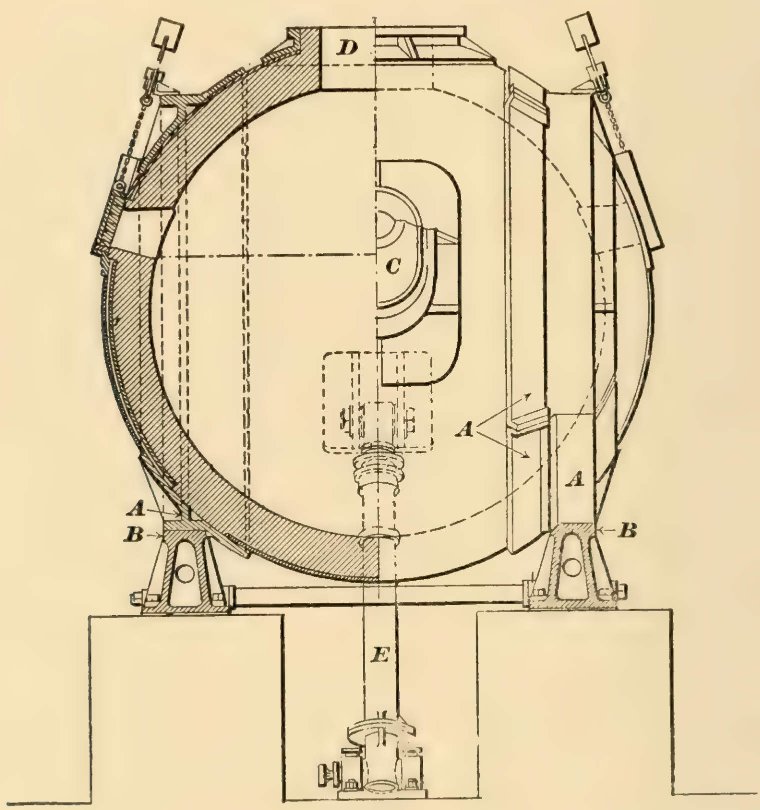


Fig. 3. Kennedy Mixer for Hot Metal.

THE LOCAL ANNEALING OF HARDENED STEEL PLATES*

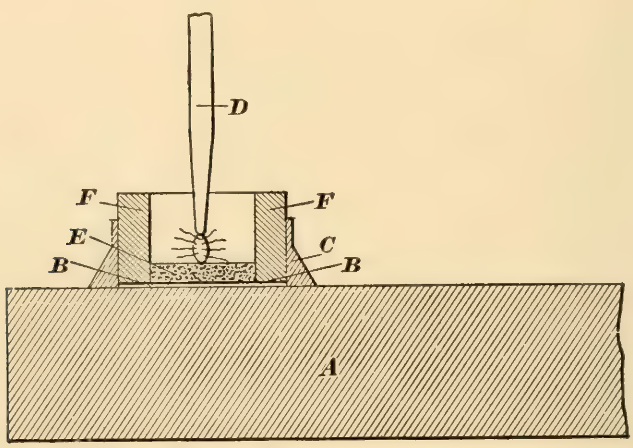
THE well known engineer, Charles P. E. Schneider, of Le Creuzot, France, has invented a method of locally softening or annealing hardened steel plates. Cemented and tempered steel plates, such as are used for armoring battleships and other structures, are not to be machined by ordinary cutting or drilling tools. Nevertheless some of these plates require for purposes of construction to be pierced or planed on the hardened surface of impact. This is frequently the case with the armor plates of gun turrets and especially so with armor belt plates. Various methods have been adopted for handling steel plates which have been finished so far as their metallurgical treatment is concerned. Among these are the five following processes: First, successive annealing, with the blow pipe with repeated drilling of the softened portions as they are reached and acted upon by the combined operations. Second, local annealing by the passage of an electric current of low tension but great volume. Third, substituting for the cemented surface one of softer metal by means of the electric arc. Fourth, attacking the cemented surface by an acid rendered more active by an electric current. Fifth, wearing away the cemented surface by emery or carborundum placed at the end of a rod or tube of plastic metal. The sole object of these several methods is the piercing of holes of small dimensions; some of the schemes are slow and present certain difficulties in successful application and others have the inconvenience of resulting in uncertain and inefficient work. None of them are asserted to be capable of application to surfaces of considerable area.

The Schneider process is said to have the following advantages. There is no need of any special plant except that required for the generation of heat; it can be applied to quite large surfaces; the heating is of brief duration and can be done on all parts of a plate even if it be considerably bent — say, to the form of a segment but one-sixth of the circumference of a circle — without necessitating the displacement of the plate; the cemented surface of the plate does not present any defects after annealing and may be cut or threaded without difficulty. The method consists principally in bringing into contact with the cemented surface a very

* "The Iron Trade Review," May 5, 1904.

fusible metal which is heated to redness by an electric arc or blow pipe. The heat of the arc is regularly and uniformly transmitted to the cemented surface through the medium of the fusible composition, the heat being transmitted to all parts which this conductor touches and solely to these parts. It will be seen, therefore, that if the surface upon which the layer of fused composition rests is limited by an enclosure consisting of some sort of mold without a bottom, it is possible to anneal the plate locally by these means at a place of any desired extent or shape.

One arrangement for carrying the project into effect is illustrated by the engraving. A is the steel plate and the upper side is the cemented hardened surface. That part of the surface which



An Armor Plate Anneal.

is to be softened will be limited by a frame F made of brick and set on a thin layer of sand B, the latter forming a joint between the brick and the steel plate. The brick inclosure is luted with clay or to use the phrase of the patent papers, has a " border of argillaceous earth " at C. The surface for treatment being thus clearly defined, the fusible composition is poured into the casting in a molten state to a height of several centimeters. An electric arc is then formed between the carbon D and the surface of the composition E. The latter is heated to redness and transmits its heat to the plate.

In order to avoid raising the temperature of the surface of the plate higher than the point of recalescence during the heating, a condition which would cause in certain metals a tempering on cooling, and also to avoid the oxidation and volatilization of the

composition, the heatings are alternated with coolings of fairly equal duration. The temperature can be estimated by plunging a small steel bar into the molten metal immediately after the passage of the current. The temperature is then seen diminishing from the surface of the composition to the face of the plate after a very short immersion of the rod. The layer of fusible composition remains red at the surface after a stop of several minutes only when the cemented surface of the steel plate is itself raised to a red heat. Of course the surface of the metal may be covered with soot or pulverized charcoal to prevent some of the waste by oxidation. Several electric arcs may be applied at equal distances when the surface for annealing is of large dimensions. The inventor points out that the fusible composition E should preferably be a metal or alloy of high specific heat. "The only essential condition to fulfill is that the temperature of fusion of this metal or alloy shall be lower than the temperature of recalescence of the part of the plate to be softened. Lead, plumbers' solder, antifriction metal, aluminium, can all be used. The heating of the fusible composition (E) which serves to transmit the heat, can be obtained by generating therein an induced electric current by means of an exterior transformer suitably arranged or by the passage of an electric current through a filament of high electric resistance, which is thereby rendered incandescent."

A FURNACE CHARGING AND DISTRIBUTING APPARATUS*

By FRANK C. ROBERTS

THE very general adoption of mechanical filling for blast-furnaces has resulted in the development of several designs of charging and distributing apparatus, while as a rule the means of conveying materials to the furnace top have been confined to adaptations of the incline plane equipped with a skip car.

In designing the various forms of charging and distributing apparatus it would appear that the principal object borne in mind has been to secure a uniform distribution of the volume of stock in the lower hopper, a condition which satisfies the requirements

* "The Iron Age," June 23, 1904.

in some instances. It is well known, however, that the dumping of a skip car leads to the separation of the coarser from the finer materials, and in cases where the furnace mixture is made up of coarse and fine stock it becomes necessary to provide some means to remix the materials, so that upon their descent into the furnace the distribution of coarse and fine throughout the mass will be fairly uniform.

Again, it will be readily conceded that a distributer which may work very well in connection with a certain class of materials may not be adapted to materials of different physical characteristics, and it is, therefore, desirable that a distributing apparatus should be capable of adjustment in order to meet the varying conditions. Manifestly it is impracticable to design automatic adjustments or to provide for the variations in the physical characteristics of stock which may occur between consecutive charges. Certain furnaces use fine materials, others coarse materials, and still others a combination of both; consequently a distributing apparatus should be capable of adjustment to meet at least the average conditions prevailing at any furnace.

The above considerations led the writer some years ago to design the herein described apparatus, the objects of the design being:

(a) To secure a uniform distribution in the lower hopper of the volume of the materials charged and to provide an adjustment which would secure this end with materials of varying physical characteristics.

(b) To provide adjustments by means of which the distribution of coarse and fine materials may be controlled.

In the accompanying illustrations Fig. 1 is a general sectional elevation of the charging and distributing apparatus, Fig. 2, a plan showing the distributing chutes in line with each other, and Fig. 3 a plan the same as Fig. 2, except that the chutes are twisted. The different parts of the apparatus are noted in the key at the side of the illustrations. In operation the skip cars H discharge into the chute E, the materials thence descending into the supplementary hopper D. Upon lowering the bell J the contents of D pass into the furnace hopper B, whence, by lowering the bell A, they are discharged into the furnace.

The objects of the design heretofore stated are secured in the following manner:

(a) *Uniform Distribution of Volume.* — It will be admitted that, if a fairly uniform volume distribution of materials is secured in the supplementary hopper D, the volume distribution in the furnace hopper B should be satisfactory. It will be noticed that the chutes E are carried by wheels F, resting on girders G, a condition which permits the ready movement of the chutes

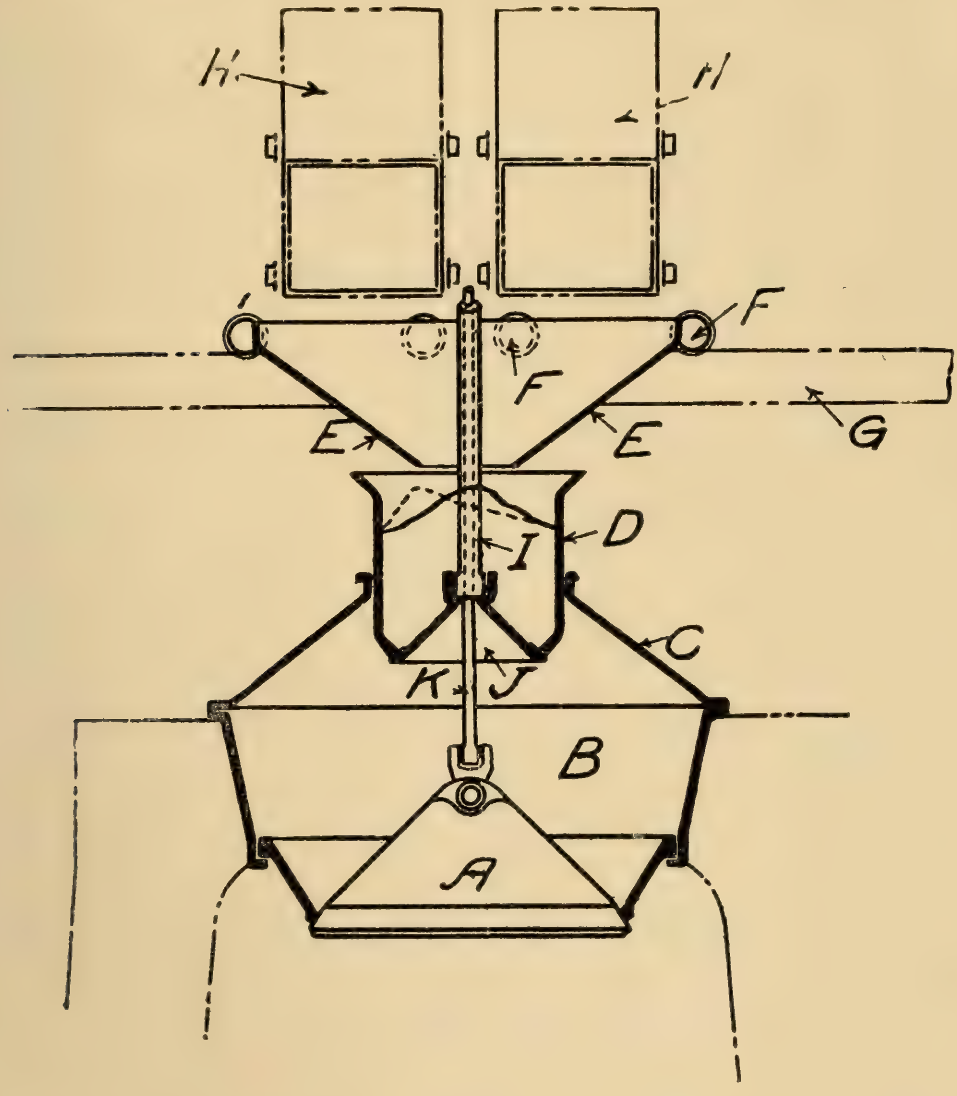


Fig. 1.

backward and forward. Should it develop upon filling the supplementary hopper D that the peak of the contents is not central, as indicated by the dotted lines, Fig. 1, the chute should be moved toward the bell rod until, for average conditions, the peak of the contents of the hopper D is approximately on the center line, as

indicated by the full line in Fig. 1. Having made this adjustment, the bell J is lowered and the materials discharged into the furnace hopper B, the passage of the materials over the bell J further assisting the distribution of volume, with the final result that the volume distribution in B is as nearly uniform as can be expected.

(b) *Control of the Mixture of Coarse and Fine Materials.*—Upon the discharge of the contents of the skip car H into the chute E there exists, as before stated, a tendency for the coarse and fine materials to become separated. The relative arrangement of the skip car H, the chute E and the supplementary hopper D is such that the materials after being discharged from the skip car must turn at right angles in order to enter the hopper D; this change of direction in combination with the rebounding action of the materials against the chute and the interference of the bell rod I to the flow of the materials is found by experience to be of great importance in that it mixes together the coarse and the fine materials. Again, it is to be noted that any fine materials which may leave the chute E slowly are delivered well toward the center of the hopper D and on top of the coarser materials previously delivered into the hopper; these fine materials upon lowering the bell J naturally become distributed throughout the volume.

Should it develop that the physical characteristics of the materials are such that the distribution of coarse and fine is not

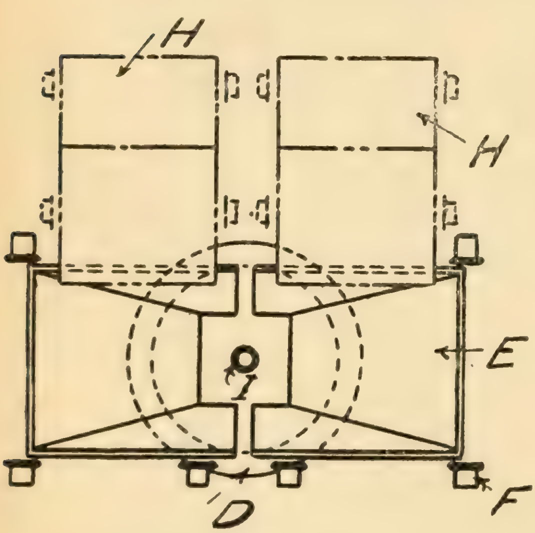


Fig. 2.

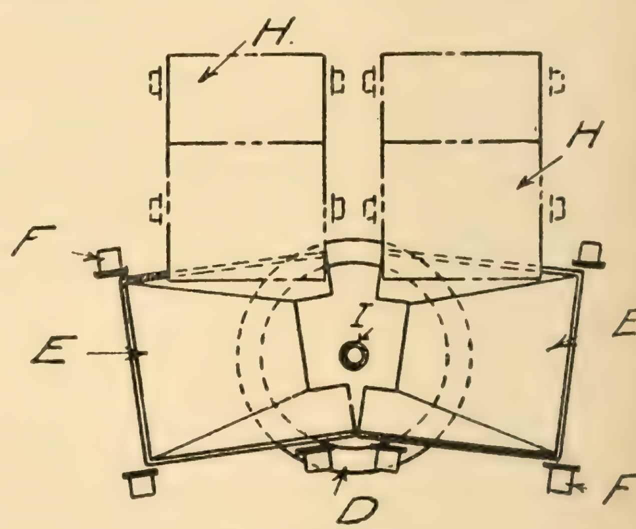


Fig. 3.

satisfactory when the chutes are located in line with each other, as in Fig. 2, a further adjustment is provided, as illustrated in Fig. 3. Fig. 2 shows the chutes located longitudinally in line

with one another and central with reference to the bell rod, while Fig. 3 shows the chutes twisted so that the inner ends of the chutes are nearer the inclined plane than in Fig. 2. The adjustment of the chutes is posssible because the wheels F are furnished with very wide treads so as to permit the chutes to be twisted and yet be supported by the treads of the wheels resting on the girders G. The object of this adjustment is to vary the opening between either side of the bell rod and the sides of the chutes. If the arrangement of the chutes in Fig. 2 permits too much coarse materials to pass into the far side (from the skip cars) of the hopper D, the chutes should be twisted as indicated in Fig. 3, whereby the openings between the bell rod I and the far sides of the chutes are decreased, while the openings on the opposite sides are increased, thus restricting the flow of coarse materials to the far side of the hopper D and facilitating their passage into the near side of the hopper D. Of course, the reverse of the foregoing conditions might prevail, in which case the chutes would be twisted in the opposite direction. It is evident that the necessary amount and direction of the twist given to the chutes depend upon the average physical conditions of the materials to be charged and will vary with almost every furnace.

It will thus be readily understood that the prime factor in the design is to secure a fair average volume and coarse and fine distribution of the materials in the supplementary hopper D, and that once this is attained the flow of the materials over the bells J and A will increase the uniformity, so that the distribution in the furnace will be as nearly perfect as the natural limits of the problem allow. It must be borne in mind, however, that while the distribution of volume and of coarse and fine may be satisfactory, yet the proper working of the furnace depends not only upon the distribution secured by the charging apparatus, but also upon the relative proportions of the bell A, the stock line and other dimensions of the furnace itself, features with which the distributing apparatus is not concerned. It is also evident that when the chutes are once adjusted it is necessary that they be maintained in the desired position; clamps are provided for this purpose.

The writer is aware, of course, that there is such a vast difference between the physical characteristics of the coke, ore and limestone that it is impossible to adjust the chutes so that the best location can be fixed upon for all three materials. Experience

has shown, however, that if the chutes are adjusted for the ore and stone charge no difficulty results in connection with the coke. This is due to the fact that the volume of the coke charge is much greater than that of the ore charge. Any lack of uniform distribution of coke in the hopper D is relatively a very small percentage of the total volume, whereas the same variation in the case of the ore charge is a much greater percentage of the total.

Experience has shown that the distribution with this apparatus is under such control that, if a furnace is working low on one side, the chutes can be adjusted so as to transfer the low point to the opposite side of the furnace; consequently there is some intermediate location for the chutes which should give a satisfactory distribution.

It may be well, also, to call attention to the fact that this apparatus has been applied with success to single as well as double skip furnaces. In the former but one chute is employed, the single skip discharging into it, as shown in the illustrations.

The advantages of the design may be summarized as follows:

1. That the apparatus may be adjusted to meet the conditions at any furnace, both for the usual requirements and for any variation which may be made in the physical character of the materials charged.

2. That should it develop, upon sounding a furnace, that one side is working more rapidly than another, adjustments may be made which will correct the irregular working.

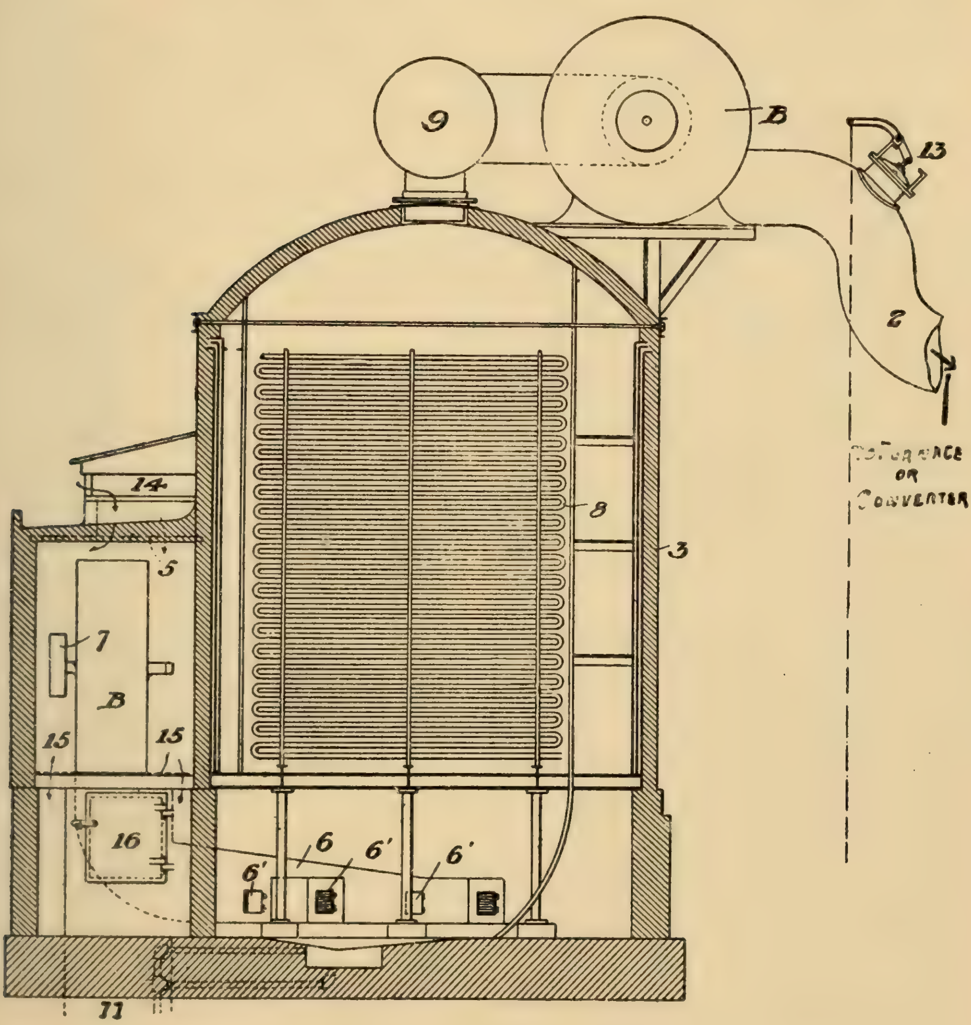
GAYLEY METHOD FOR EXTRACTING MOISTURE FROM AIR FOR FURNACE OR CONVERTER*

JAMES GAYLEY, vice-president of the United States Steel Corporation, has designed an air refrigerating apparatus for the purpose of artificially cooling the air before compression by the blowing engine preparatory to its entrance to the blast-furnace or converter. His process for the condensation of moisture is now in operation at the Isabelle furnaces of the Carnegie Steel Company, Pittsburg.

* "Industries," June 9, 1904.

Mr. Gayley seeks to make uniform from day to day the amount of moisture taken in by the furnaces and designs to accomplish this by rendering the air practically dry by means of refrigeration. His method is explained in the accompanying illustration.

Referring to the illustration, 2 is the pipe through which the



Gayley Air-Refrigerating Apparatus.

air passes fron the refrigerator or drying chamber to the blowing engine and under compression from thence to the furnace or converter. Air is drawn by a blower or fan B through the inlet 5 and fed into the refrigerating chamber through the distributing conduits 6, or the blower B′ used instead to aspirate the air through the refrigerating chamber.

B and B′ show two locations for the fan, as it may be preferred either to feed or aspirate the air through the refrigerating chamber, but it is not necessary to use both. When the fan B is used, the air enters the pipe 5 and is forced by the fan, which is power-driven, through the driving wheel 7, driven by a motor and preferably into the distributing pipes 6, which lead into the refrigerating chamber 3 and open at various points therein with valve-controlled openings 6′, so that the air shall be evenly distributed under the refrigerating pipes 8 and will come into contact with these pipes, which are cooled to a low temperature by anhydrous ammonia.

The cooling agent is anhydrous ammonia, furnished by an ice-making machine of suitable design. On evaporation it produces a very low temperature, though other refrigerants producing intense cold, such as carbonic anhydrid, may be employed. The moisture in the air is deposited on these pipes in the form of snow, and the dried air passes into a receiving chamber 9 and thence through the pipe 2 to the blowing engine from where it is delivered to the furnace or converter. If the blower or fan B′ is used, the fan B is dispensed with and the air is aspirated from the inlet-pipe 5 to the blower B′ and then fed into the high-pressure blowing engine.

If for any reason the blower B should become inoperative, the air would pass through the hood or air inlent 14 and opening 5 of the fan-room and through the open floor 15 of the fan-room into the cellar and into the fan-discharge pipe 6 through a door 16, which must be opened as soon as the fan is not in operation. A by-pass is thus provided for the air. If the blower B′ is used, a special by-pass must be provided to admit air to the engine when the fan becomes inoperative.

On the pipe 2 is a valve 13, which is used when the engine is not in operation. When this valve is opened, a small current of air from the blower flows through the refrigerating chamber out of the valve opening, thus maintaining the refrigerator appliances in normal working condition and by the refrigerant absorbing heat preventing the frosting of the refrigerant pipes. The blower B or B′ is auxiliary to the blowing engine. It is valuable because it relieves the blowing engine of a large amount of work due to the back pressure or exhaustion of air through the conduits and lines of refrigerating coil, which obstruct its free passage and

would cause the engine to draw in less air than if the inlet valves were freely exposed to the atmosphere.

The pressure developed by the blower is much smaller than that developed by the blowing engine and need only be very small — one ounce or less — and even if only sufficient pressure is developed thereby in the refrigerating chamber to give the normal atmospheric pressure at the engine inlet valves the advantage of the auxiliary blower would still be practically attained.

The air that is propelled by the blower presses into the distributing pipe 6, then upward and around the coils of pipe 8, which are very cold, due to the refrigerating fluid, and on these pipes the moisture is condensed in the form of frost. It then passes into the receiver 9, then through conduit 2 to the blowing engine, from which it is fed under pressure to the furnace or converter either directly or through a stove and maintained under pressure from the time it leaves the engine until it enters the furnace or converter.

When the pipes in the refrigerating chamber become covered with frost, the frost is thawed off by passing the hot ammonia gas through one of the coils or series of coils, and the water melted therefrom will collect in the pit 11 and can be withdrawn. Meanwhile the series of the coils can be used with refrigerant in the usual way, and by thus thawing the series successively instead of thawing all of them at once the operation of the apparatus is not interrupted and can be made continuous in a single chamber.

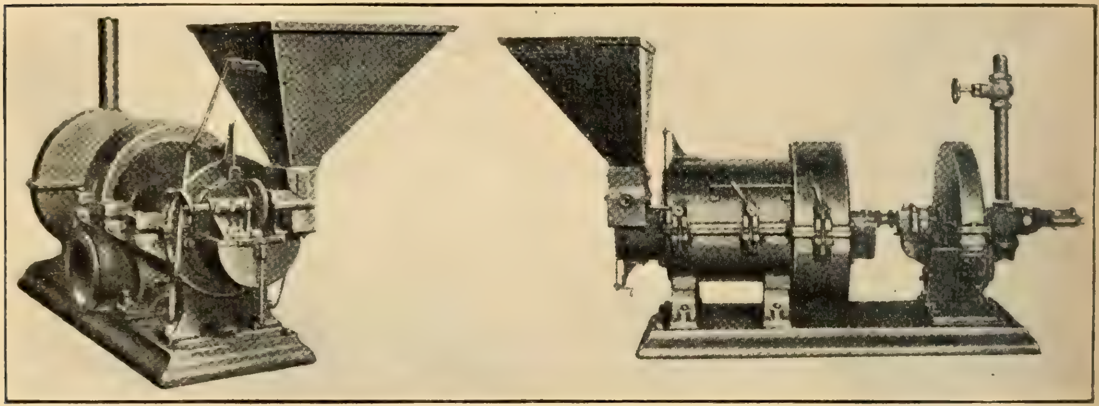
It will be observed that on account of the air being constantly in rapid motion and under pressure and the enormous volume required the methods usually employed for extracting a portion of the moisture from small volumes of air in applying it to drying grain, cooling-rooms, etc., are not applicable to blast-furnaces and converters, since in many of these methods the air is allowed to expand, which in itself is the most serviceable refrigerating process and simplifies the operation to a great extent, while in Mr. Gayley's process there is no substantial expansion of the air prior to its introduction into the furnaces.

POWDERED COAL FOR STEEL ANNEALING*

By H. J. TRAVIS

AMONG the various uses to which powdered coal as a fuel has been recently applied, we find an interesting instance at one of the largest works of the United States Steel Corporation. An annealing furnace for steel castings is there now heated with this fuel instead of oil, the latter having been used for several years.

A pulverizing apparatus as shown in the half-tone was in-



Coal-Pulverizing and Feeding Apparatus.

stalled in front of one of the annealing furnaces, and experiments were begun to determine the availability of this system for this purpose. This machine pulverizes and feeds the coal and furnishes the necessary air for complete combustion. Feeder, pulverizer, fan and a steam turbine are mounted on one shaft, the turbine driving the revolving parts about 2,500 revolutions per minute, giving the pulverizing bats a speed of about 11,000 feet.

A small quantity of kindling placed in the furnace serves to ignite the incoming cloud of coal dust and air, thereby producing a high temperature. The tables give the results of observations and tests of an annealing furnace in the steel mill of the foundry of these works, using pulverized coal as fuel.

The furnace was charged with steel castings of various sizes, aggregating in weight 22,602 pounds. From the time that the powdered coal feeder started to the end of the heat, 1½ hours had elapsed. Three hundred pounds of wood were used in start-

* "American Machinist," June 16, 1904.

ing the fire. To obtain the necessary draft at the furnace to carry off the gases of combustion, a small jet of steam was used in the stack. The steam consumption of turbine for driving the apparatus and the blower was accurately determined and was used as a basis for the calculations for the following results:

Total time of annealing from starting of fire, 1.5 hours.

Total weight of castings annealed, 22,602 pounds.

Total coal burned, 796.5 pounds.

Total amount of steam used by turbine and blower, 1,930.5 pounds.

Coal burned per hour, 531 pounds.

Steam used by turbine and blower per hour, 1,287 pounds.

Coal used per ton (2,240 pounds) of steel annealed, 78.8 pounds.

Steel annealed per pound of coal burned, 28.3 pounds.

Steam used per ton of steel castings annealed, 192.8 pounds.

Turbine and Blower

Average revolutions per minute, 2,570.

Average pressure on turbine nozzles, 85.4 pounds.

Steam used per hour by blower, 33 pounds.

Steam used per hour by turbine, 1,254 pounds.

Boiler horse-power to supply steam for blower, 1.12.

Boiler horse-power to supply steam for turbine, 42.67.

Total horse-power required, 43.79.

Total boiler horse-power per 100 pounds coal burned per hour, 5.49.

Pressure in furnace with blower on, 0.10 inch.

Pressure in furnace with blower off, 0.05 inch.

Temperatures in Furnace by Electrical Pyrometer

The positions of holes in furnace walls through which temperatures were taken were arranged and numbered beginning at the side nearer the apparatus or delivery tube, and the last, No. 4, beyond the stack, No. 3 being nearer the uptake and showing the highest temperatures.

Time of Taking Temperatures	1 °F.	2 °F.	3 °F.	4 °F.
10.48 a. m. to 10.55	1025	1200	1275	1000
11.05 " " 11.10	925	1250	1350	975
11.19 " " 11.23	1000	1350	1500	950
11.40 " " 11.45	1025	1350	1525	960
11.59 " " 12.03	1250	1450	1500	1200

It will be observed that the furnace is hotter at the end farthest from the stoker and nearer to the stack; on this account it may be well to put the largest castings in this end, to secure a more uniform annealing.

Fifteen minutes after starting the stoker, the furnace was filled entirely with a reddish yellow flame which seemed to come in contact with all parts of the castings. The maximum observed temperature did not rise above 1,525° F. This comparatively low temperature is no doubt caused by the flame coming in contact with the steel castings, as this same machine has stoked dust in a boiler furnace effecting a temperature of 3,800° F. The residue in the bottom of the furnace after the heat was found to be a brown powder containing no combustible matter. Gas analysis of samples taken from the furnace showed the combustion to be good.

Average analysis:

CO_2	14.4 per cent
O	3.2 per cent
CO	1.2 per cent

A certain amount of CO would be expected in a gas containing as high a percentage of CO_2.

Analysis of coal used was as follows:

Moisture	0.5 per cent
Volatile matter	21.0 per cent
Fixed carbon	69.3 per cent
Ash	9.2 per cent
Sulphur	0.72 per cent

Comparison of the cost of annealing with oil and powdered coal:

Pulverized Fuel

Taking the cost of coal at $2.75 per ton and a boiler horse-power year (7,200 hours) at $45, the cost to anneal one ton of castings (2,240 pounds):

For coal alone	$0.097
For steam (turbine and blower)	0.041
Total	$0.138

Oil

With the oil annealing furnace the average weight of castings charged was about 4½ tons; to anneal this, three burners were used for ten hours. Cost to anneal one ton (2,240 pounds) of castings:

For oil alone	$1.40
Compressed air to vaporize oil	0.45
Total	$1.75

From the above, the cost of annealing by pulverized fuel is 7.87 per cent of that for annealing with oil.

The steam consumption of the apparatus has been charged as given by the engineers of this company, but there is some error in the figure, "1,254 pounds per hour," as given as consumed by the turbine as it is impossible to blow this amount of steam per hour through the six nozzles at 85 pounds pressure. This error no doubt has been made in separating the steam used by blower from that used by the turbine, as numerous tests in boiler practice have shown a steam consumption of from 480 to 500 pounds per hour when pulverizing 550 pounds of coal and developing nine turbine horse-power; the total steam per hour, however, 1,287 pounds, is correct.

PIG IRON AS PRODUCE*

THE proposition for the New York Produce Exchange to deal in pig iron storage warrants must strike the unsophisticated reader as somewhat anomalous, and yet why not pig iron as well as the other raw materials? The storage warrant system or the dealing in those certificates representative of actually existent material is no new thing. We certainly called attention to some features of the business fifteen years ago. The system, as is in practical operation in the United States to-day is thus described in the "Journal of Commerce" (New York):

"The storage company known as the American Pig Iron Storage Warrant Company has established storage yards in various iron-producing districts under strict supervision of the company's agents. The producer of iron who is desirous of placing the product of his furnace in the custody of the storage company issues a certificate showing the weight and the grade, by fracture or by analysis, when the iron is delivered into the storage yard. The agent of the company also issues a sworn certificate, giving practically the same details regarding the same iron as is contained in the furnace certificate. The work of the yard agents of the storage company is subject to verification by an inspector. Upon the delivery of the storage and the furnace certificates to the warrant company, a warrant is issued, signed by the president and secretary of the company and countersigned by the fiscal or transfer agent of the company — a bank or trust company. Thus issued, the warrant is practically the same as a guaranteed warehouse receipt, and may be bought and sold as are stocks or bonds. The warrant may be used as collateral for a loan if desired; banks have loaned upon such security from 50 to 90 per cent of the market value of the iron represented. The warrants may also be dealt in on commercial or stock exchanges, as in Europe. The holder of the warrant pays to the storage warrant company 2½ cents per ton per month for carrying the iron. The consumer, as well as the producer of iron who deals in warrants, does so to obtain protection against fluctuations in the market for the actual metal during the life of long contracts."

This arrangement, as it stands, and so far as the producer

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* "American Machinist," March 31, 1904.

and the consumer are concerned, has its evident advantages. It seems to be quite a different thing when it is proposed to make the pig iron certificates easy of handling by those who are neither producers nor consumers, nor legitimate middlemen. It is the fictitious transactions, the buying and selling of the hypothetical — not the hypothecated — which leads to business derangement, and no arrangement which merely makes it easier to buy only for the sake of selling, and to sell merely for the sake of buying, with no function of promoting the distribution or use of the actual goods, can seem to be in the interest of genuine and legitimate commerce or manufacture. The recent performance with cotton has crippled most mills and stopped many throughout the civilized world, and the increasing of the possibilities of cornering pig iron or of producing artificial and unwarranted advances or depressions of prices cannot well be looked upon with favor by the plodding men of the shop. It is fortunate for pig iron and its friends and dependents, that its production is not dependent upon the sun and the rain or the ravaging things which fly or creep, not so touched with the element of uncertainty as is the other produce, and that therefore the opportunities for and the temptations to gigantic speculation in it are not so unlimited.

ALLOTROPIC MODIFICATIONS OF IRON*

By T. M. LOWRY

THE extraordinary effects produced by the association of a little carbon with metallic iron, and the delicate shading of properties that can be produced by softening, chilling and tempering, have been known and made use of from the very earliest times; but it is only in recent years that the investigations of Osmond, Roberts-Austen and others have elucidated the complex problem presented by this series of alloys. The discovery that iron is trimorphous, and the accurate determination by Roberts-Austen of the transition temperatures, laid the foundations for the scientific study of the alloys of iron; and on this basis all the more important properties of these alloys can be accounted for. *Gamma* iron, which is stable, above 890° C., appears to possess all

* "Technics," May, 1904.

the properties of the hardest chilled steel, whilst *Alpha* iron, which is stable below 755° C., is simply a soft, magnetic, pure wrought iron. The properties of *Beta* iron, which is stable between 890° C. and 755° C., are not very fully known, but are to some extent intermediate between those of *Alpha* and *Gamma* iron.

The only important alloys of iron are those produced by associating it with elements that are isomorphous with *Gamma* iron, but not with *Alpha* or *Beta* iron. Thus, solid *Gamma* iron will form mixed crystals containing up to two per cent of carbon, but the whole of this is thrown out of (solid) solution when the *Gamma* iron passes into *Alpha* iron, as carbon is quite insoluble in this modification of iron. The effect of associating carbon with iron is, however, to greatly increase the range of temperature within which *Gamma* iron is stable: in presence of 0.8 per cent of carbon it does not begin to change directly into *Alpha* iron above 690° C. Even more pronounced effects are produced by alloying with manganese and nickel, either with or without carbon. The self-hardening steels, the properties of which were described in the February number of this journal, are simply alloys in which the lower limit of stability of *Gamma* iron is brought down almost to atmospheric temperatures by associating it with carbon and manganese, and the numerous commercial applications of nickel steel depend on the fact that the limit of stability of *Gamma* iron is steadily lowered by the addition of nickel, until in an alloy containing about 35 per cent of nickel the transition temperature is approximately 0° C.

The second important characteristic of the alloys of iron depends on the property possessed by the associated elements of reducing the rate at which the different modifications of iron are converted one into another. Thus *Gamma* iron, which, when pure, cannot be obtained at ordinary temperatures, as it changes into *Alpha* iron immediately below the transition temperature, is obtained with the utmost ease by chilling a steel containing only a small percentage of carbon: when once brought down to atmospheric temperatures, it only softens extremely slowly. If, however, a chilled steel tool becomes hot in working, the rate of change from *Gamma* into *Alpha* iron increases and the tool becomes soft. In the self-hardening steels the transition-temperature is reached, and the *Gamma* iron becomes stable.

The remarkable properties of steels containing about one

part of nickel to two of iron are due to the fact that the conversion of *Gamma* into *Alpha* iron is just beginning at ordinary temperatures. The non-expansive alloys which were referred to in our April issue, owe their unique properties to the fact that *Alpha* iron occupies a greater volume than *Gamma* iron; but whereas in pure iron the expansion takes place sharply at the transition temperature, in the non-expansive alloys it is spread over a large range of temperature, *and just counterbalances the normal contraction due to fall of temperature.*

The elastic properties of nickel-steels are quite as remarkable as their non-expansive properties, and promise to lead to an even greater demand for them. *Gamma* iron is far more rigid than *Alpha* iron, and has a much larger modulus of elasticity. There is, therefore, a large decrease in passing from *Gamma* iron to *Alpha* iron, and in the non-expansive alloys this decrease, instead of taking place abruptly, is spread over a wide range of temperature, and more than counterbalances the normal increase due to fall of temperature. The result is that alloys containing from 29 to 45 per cent of nickel have an altogether unique *positive* temperature coefficient of elasticity, whilst two alloys (having approximately the compositions indicated) will have a modulus of elasticity which does not vary with the temperature. Whilst the non-expansive alloys render it unnecessary to compensate for expansion in clock-pendulums, their elastic properties promise to effect an even more remarkable revolution in the watch-making industry, since by using a nickel steel hair-spring of suitable composition, it will be unnecessary to employ any form of compensated balance-wheel.

VANADIUM STEEL*

Constitution, Properties, and Practical Application of Alloys of Vanadium and Steel

By LÉON GUILLET
Académie des Sciences

ALTHOUGH frequent notes have appeared in the technical press concerning the valuable qualities of vanadium steel there has been no published record of systematic researches into its properties. For this reason the paper of M. Léon Guillet,

* "Engineering Magazine," April, 1904.

presented before the Académie des Sciences, and published in "Comptes Rendus," is of importance and interest.

M. Guillet has made investigations upon two series of vanadium steels, the first containing about 0.20 per cent of carbon, and the second 0.80 per cent. In each series the proportion of vanadium was increased from 0 to 10 per cent, especial attention being given to those containing 3 per cent of vanadium, as being of the greatest industrial importance.

Considering first the results of micrographic examination, M. Guillet etched specimens of the 0.20 carbon steel with picric acid, and observed no material difference from carbon steel in appearance until the content of vanadium exceeded 0.7 per cent; the pearlite was the same in appearance as in carbon steels, but the ferrite was rapidly colored a dark brown. As the content of vanadium was increased there appeared distinct white grains in the pearlite, these being plainly visible in relief upon polishing. These white grains developed with increasing proportions of vanadium until the pearlite was no longer visible, and when the alloy contained more than 3 per cent of vanadium the white grains alone appeared, increasing in number and magnitude as the percentage of vanadium was increased.

Similar results were obtained with the steel containing 0.80 per cent of carbon. Up to 0.5 per cent of vanadium the structure was pearlitic, after which the white grains appeared and rapidly increased; and above 3 per cent nothing else was to be seen. This product is a carbide, either a carbide of vanadium or a double carbide of vanadium and iron.

Three groups may be distinguished in considering vanadium steels:

1. Steels presenting the same structure as carbon steels;
2. Steels containing pearlite and vanadium carbide;
3. Steels in which all the carbon appears in the latter form.

The mechanical properties may be stated broadly as follows:

Steels of the first and second groups show a much higher ultimate strength and elastic limit than ordinary steels of the same carbon content; the elongation and reduction of area are medium, and they are much harder and more brittle than carbon steels. Thus, a steel containing 0.131 carbon, and 0.60 vanadium showed an ultimate resistance of 98,000 pounds and an elastic limit of 78,000 pounds. With a steel of 0.112 carbon and 1.04 per cent va-

nadium the ultimate strength rose to 129,000 pounds with an elastic limit of 107,000 pounds per square inch, the elongation being from 10 to 12 per cent.

Steels of the third group, containing 3 per cent and more of vanadium show very low ultimate strength and elastic limits, the elongation becomes high, while at the same time they are very brittle. Thus a steel containing 0.187 per cent carbon and 2.98 per cent vanadium showed an ultimate strength of about 67,000 pounds and an elastic limit of about 27,000 pounds; while with 0.12 carbon, and 10.27 vanadium the ultimate strength fell to 43,000 pounds and the elastic limit rose to 30,000 pounds. A steel containing 0.737 carbon and 7.85 per cent of vanadium had an ultimate strength of 43,000 pounds and an elastic limit of 19,000 pounds per square inch. For these alloys the elongation ranged from 16 to 24 per cent.

All of the vanadium-steel alloys are annealed to a slight degree by heating for a short time to a temperature of about 900° C. If the annealing is prolonged and a high temperature maintained, a precipitation of graphitic carbon occurs in a manner similar to that observed with other steels. Quenching produces a remarkable hardness in the steels of the first two groups, while it produces a slight softening of the third group. These effects appear to be produced regardless of the temperature at which the steel is quenched. H Guillet extended his experiments in this respect up to a temperature of 1,200° C., and in no case did the quenching materially change the structure.

In general the following statements may be made concerning vanadium steels:

They may be divided into three distinct groups, one of these holding an intermediate position between the other two. Each of these groups may be characterized by its mechanical properties and those containing the special constituent present very remarkable properties. The experiments show that industrial applications may be expected only of those steels containing less than 7 per cent of vanadium, and hence it is upon these alloys that further experiments should be directed.

The brittleness of the vanadium steels apparently prevents them from being used for the production of cutting tools, for which they would otherwise appear to be well adapted, but it is possible that this property may be modified by the addition of

nickel. M. Guillet is at present engaged upon experimental researches upon nickel-vanadium steels, and promises to make his results public before long.

THE SMALL CONVERTER V. THE OPEN-HEARTH FURNACE IN THE STEEL FOUNDRY*

By L. UNCKENBOLT
Charleroi

IN the technical press recently, a writer has set forth the economical advantages of the employment of a small Bessemer plant in foundries producing steed castings. The author desires to controvert the assertion that it is possible to replace, with advantage, the existing open-hearth furnace by a small converter, and he is of opinion that there is a separate field for each, economically speaking. It must be allowed that with the Bessemer plant the output can be without loss made to correspond with the demand. It is also possible to make, not only small and thin castings, but pieces of considerable thickness and weight. In the case of a new undertaking, before the acquisition of regular customers and in the absence of a trained staff of workmen, the advantages mentioned would seem to tell decidedly in favor of the small converter. On the other hand, the Bessemer process of making steel is more expensive than the open-hearth method.

On this account we often find foundries, after working for a number of years with the small converter and having thus acquired a regular connection for their manufacture, decide upon the erection of an open-hearth furnace. With the combination of an open-hearth furnace and a small Bessemer plant, anything in the steel casting line can be turned out. The advantages of the former, however, are not few. First of all, no machinery is necessary for working the furnace, and there is again the facility of ascertaining the actual composition of the bath by taking samples at frequent intervals. It must, however, be admitted that an attentive operator is always cognizant of how far the process in the converter has advanced. The appearances of the flame, together with the measurement of the blast pressure and of the time, enable him to follow the various stages with accuracy. Again, in the open-hearth furnace the waste of metal is less, consequently

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* "The Iron and Coal Trades Review," April 8, 1904.

the cost of the raw material comes out lower. On the other hand, there is certainly the disadvantage that it is impossible to cast pieces exceeding a certain weight, since several charges cannot be collected, as they can with the converter, for one casting operation. Further, most steel foundries utilizing the open-hearth furnace find it desirable to run at the same time a rather expensively working crucible furnace, with from four to six crucibles, the produce of which is employed for filling-in purposes. In the open-hearth furnace, on the other hand, it is very easy to use up the large spoilt castings, whereas with the small converter this is not so easy, because they have to be broken up, which is often a rather dear operation.

From the reasons stated it will be seen that the decision of the question as to which is the most economical is not a simple matter. Nowadays, a small open-hearth furnace, with a capacity of from six to seven tons, including the gas producer, can be obtained for £2,500. On the other hand, we may put down a cupola furnace, with blower, at £250, and the converter, with blowing engine, at £500. The first outlay for the former is £2,500, as against £750 for the latter. In the case, moreover, of the Bessemer plant, we have an extra current expenditure, corresponding to the cost of from 50 to 75 H. P., for working the blowing engine, the crane, and the tilting machinery. In the writer's opinion, however, the consideration of the initial cost will not, as a rule, be sufficient to decide which system is to be adopted. The advantages of the small converter will only preponderate: (1) Where it is desired to produce light casting in large quantities, and the orders for heavy ones are rare; and (2) in all cases where a business connection has to be established, and, consequently, the output from time to time will fluctuate considerably. If, however, it be decided to forego the making of light castings, and one can rely upon a tolerably uniform absorption of the produce with a well trained staff of molders, the advantage will remain with the open-hearth plant. In the latter, large furnaces are not desirable; the right size is from six to seven tons. It is better to have two small ones than one large one, say, of 12 tons capacity, because should at any future time the sales drop, the loss is twice as great with the large one. With the open-hearth furnace, once it is started it must be kept continuously working, otherwise the expenses mount up very considerably.

BLAST-FURNACE SLAG AS A STRUCTURAL MATERIAL*

By JOS. A. SHINN

DURING the year 1903 there was produced in the United States upwards of 10,000,000 gross tons of blast-furnace slag, a quantity sufficient to cover 2,000 acres, or more than three square miles, to the average depth of three feet, if in the form of broken stone.

Of this quantity, a few hundred tons were used in the manufacture of slag wool; less than 75,000 tons in the manufacture of Portland and Pozzuolani cements, and possibly 1,000,000 tons as substitutes for broken stone, gravel for roofing, etc.

The balance, or more than 9,000,000 tons, was deposited in low ground or unsightly heaps near the furnaces, or was used by railroads for embankments and ballast.

Of the total quantity produced, 45 per cent was produced in the State of Pennsylvania, and 23½ per cent, or more than 6,000 tons per day for every day in the year, was produced in Allegheny county. At no other place in the world is an equal quantity produced in so limited an area.

The whole of this latter quantity could be utilized in construction with a gain in quality of structures produced, or at a saving of cost, or both.

As early as 1770, granulated slag was recognized as furnishing a material of very superior quality for the making of mortar as compared with common sand.

From about 1820 to 1870, numerous attempts were made in England to utilize the slag commercially, by casting it into blocks for road paving, but with indifferent success.

In 1840, Edward Parry, of Wales, commenced the manufacture of slag wool, but it was not until its manufacture by Krupp, at Essen, and Luurman, at Georgs Marienhütte, in Hanover, about 1875, that it became a recognized commercial product.

In 1870, Mr. Fritz Luurman, a well-known furnace engineer, began the manufacture of bricks at Osnabrück, Germany, using 90 per cent to 94 per cent of granulated slag, and 6 per cent to 10 per cent of common lime. Of these bricks Mr. Luurman says: "They are adapted to all kinds of sub-aqueous and subterranean

* Abstract from a paper read before the Engineers' Society of Western Pennsylvania, March 22, 1904.

foundation work, as well as to super-structure, and their refractory qualities make them suitable for the linings of lime kilns, and boiler-furnace stacks, and for hot-blast stoves.

In 1873, the Tees Slag Co., of Middlesboro, England, began the manufacture of these bricks, but instead of using lime for the matrix, they prepared a crude slag cement, made by the wet process, consisting of 70 per cent granulated slag, 15 per cent lime hydrate, and 15 per cent of calcined iron ore, ground to about 60 mesh, and used 15 per cent of this mixture with 85 per cent granulated slag in making bricks, making the lime addition but 2.15 per cent of the whole.

They also executed a number of engineering works in concrete, using this crude cement for the matrix and broken hard slag for the aggregate, among the early structures being a six-story mill building, the foundation for a 100-ton steam hammer, arches under a large brick station and platform for the London & Great Eastern Railroad, and a number of foundations for rolling-mill machinery.

The manufacture of slag bricks is now carried on in all of the iron-producing districts of Europe. This industry, together with cement and aggregates, consumes a large part of the slag produced.

In 1883 a patent was issued to Bosse & Walters, of Germany, for a cement consisting of 85 per cent granulated slag and 15 per cent common lime hydrate, ground together to a fineness of 90 per cent, through a 200-mesh screen.

The term Pozzuolani cement has been given to this product because of the similarity of physical appearance and hydraulic action of Pozzuolani and furnace slag.

Pozzuolani is of volcanic origin, and was produced by the molten lava coming in contact with water during its eruption. Its chemical constituents are mainly silica, alumina and iron, lime being present usually to the extent of three per cent and seldom over six per cent.

Pliny and Vitruvius mention that during the time of the Roman Empire, Pozzuolani was used in place of sand, in the construction of some of the viaducts and aquaducts which have stood for centuries and parts of which are still in existence, monuments of engineering skill.* "At Pozzuola, a breakwater, consisting of 24 arches, was constructed of brick, faced with

* "American Encyclopedia."

stone, the mortar for which consisted of Pozzuolani and common lime. Although constructed more than 1,800 years ago, 13 of these arches are still standing above water."

As in slag, the silica in Pozzuolani is soluble in the presence of lime, and to this fact is due its hydraulic quality. In modern times hydraulic cement has been made by grinding Pozzuolani and mixing it with lime hydrate in the same manner as is now done for slag cement.

For many years it has been the practice of some of the manufacturers of Portland cement, in Germany, whose works were located near blast-furnaces, to mix a quantity of granulated slag with their cement. It was claimed that it not only cheapened the product, but that it materially improved the quality of the cement. The latter claim was denied by those not using slag and resulted in the adoption of a definition for Portland cement by the Verein Deutscher Portland Cement Werke, which excluded from membership those using slag.

With the further development of the Portland cement industry, slag was in some works subtituted for marl and limestone, in the manufacture of Portland cement, and was found to be capable of producing a stronger cement than the latter materials. The term "Eisen Portland Cement" was applied to the new product.

This was followed by the organization of the Verein Deutscher Eisen Portland Cement Werke, embracing those who made Portland cement from slag, and those who mixed slag with either kind of Portland cement. It is claimed by the latter association:

First. That Portland cement made from slag is stronger than when made from marl or limestone; and

Second. That the addition of 30 per cent of granulated slag to any Portland cement adds materially to its strength while reducing its cost.

These claims have received recognition by such authorities as Tetmajer, of Zurich; Michaelis, of Berlin; Le Chatelier, of Paris; Passow, of Hamburg, and Mr. J. H. Stead, member of the British Institution of Civil Engineers, of Middlesboro, England. And in the report made to the Swiss Government, by Dr. L. Tetmajer, Director of Tests of Building Materials at

the Swiss Polytechnic School of Zurich, he says of slag Pozzuolani cement: "I consider slag cement a binding material, par excellence."

Literally interpreted, it was intended to convey the opinion that it was equal to the best Portland cement, if, as previously stated by him, it was supplied with a sufficient quantity of water during the early period of induration, it requiring more water than Portland cement at that time.

Regarding the theory of the deleterious influence of sulphur in slag cement, Dr. Tetmajer says: "I have yet to learn of an authenticated instance of injury to a structure in slag cement due to the presence of sulphur."

For the manufacture of slag Pozzuolani cement, all authorities agree that the slag should be highly basic, the furnace working hot, and that the quicker the slag is quenched the better the cement.

The ordinary method of granulation is by running the molten slag into a tank of water, in connection with a stream of water under low pressure (usually jacket water) for the purpose of breaking up the mass and supplying the loss due to evaporation.

The chemical analysis of granulate differs but slightly from that of air-cooled slag, usually showing a slight loss of sulphur. According to Tetmajer, the physical condition undergoes a marked change, the elements being more or less dissociated according to the rapidity of quenching, and the silica being rendered quite soluble in the presence of free lime. Le Chatelier also discovered that granulate contains a large proportion of latent heat, while air-cooled slag contains very little, this result also depending on rapid quenching.

Experiments made by the writer for the purpose of producing a material from furnace slag for use as a substitute for river or bank sand, for mortar and other purposes, without the necessity of a second operation of crushing or grinding resulted in a granulate of greater weight and density than common granulate, finer and more uniform in size, with a well defined granular structure, and owing to the more rapid quenching capable of producing a mortar of greater strength when combined with either cement or lime, because of its greater hydraulic energy.

To this material I have applied the term "slag sand," in

contradistinction to that of slag granulate as applied to the lighter and less hydraulic form.

It is produced by projecting two jets of water under a pressure of 40 to 80 pounds per square inch, according to the size of the slag stream, in the line of the flowing molten slag.

The jets now used are 10″ wide, and ⅛″ thick; one being placed immediately below and on a line with the runner spout and the other above and at nearly a right angle to the first.

The slag flows from the runner spout and falls on the lower jet of water, but does not penetrate it, owing to the high pressure, while the velocity of the water causes the slag to draw into a thin sheet. The upper jet striking this sheet a few inches from the end of the runner spout, causes its thorough disintegration and instant quenching, and it falls into the tank below.

The opposition encountered in Germany and France by the manufacturers of the various slag cements has resulted in the production of a very considerable literature on the general subject of slag utilization, and with the further result that the opposition has been placed upon the defensive.

Unfortunately for us, the literature of slag is almost wholly in the German and French languages.

While the Portland cement industry had its inception and early development in England, it is to Germany that we are indebted for its improvement in strength and reliability, and a thorough knowledge of its chemical action. That slag has been in use for more than 30 years in a country where cheapness is not a first consideration in engineering construction, but where ultimate economy is a necessity, and that it has made steady progress until it has been recognized by the best authorities as not only equal to the best material for particular structural uses, but as having no equal as a binding material in concrete and mortar, its use being not only permitted but specified in important state, municipal and other engineering works, is a sufficient guarantee of its strength and stability to warrant the American engineer in encouraging its adoption here.

The probable effects of the sulphur contained in slag, when the latter is used in any of its forms in concrete-steel construction, is answered in "Notes from Report No. IX of Insurance Engineering Experiment Station, Boston, Mass."

"The results of the tests, which were carried out under

various conditions, lead to the conclusion that structural steel, if encased in a sound sheet of good concrete, is safe from corrosion for a very long period; longer than the changes in our cities will allow any building to remain. It is a necessity, however, to be sure that the steel is properly encased in the concrete, and because of the difficulty in getting sound work, many engineers will not use concrete. This is especially true of cinder concrete in which the porous nature of the cinder has led to much dry concrete and many voids and much corrosion. There can be no question that cinder concrete has rusted great quantities of steel, not because of its sulphur content, the danger from which is a myth, but because it was too dry. If cinder concrete be mixed wet, and well mixed, it may be trusted as much as stone concrete, so far as corrosion is concerned."

I hold that the same is true of slag concrete. Oxidation of the sulphur in the slag and consequent corrosion of the steel from that cause cannot take place if the concrete is sufficiently solid to exclude the air.

The converse of this proposition is true, that no matter what materials enter into the concrete, if it is not made sufficiently solid to practically exclude the air, corrosion of the steel will inevitably result.

Experiments and developments in the utilization of slag have progressed along the same lines in the United States as in Europe, with the exception of brick making.

The manufacture of slag wool was commenced by Alexander D. Elbers, in New Jersey, about 25 years ago, and is now carried on commercially in a number of places.

The Illinois Steel Co. has been making slag Pozzuolani cement since 1893, and it is now being made at Sparrows Point, Md., Youngstown, O., and at other places.

The Illinois Steel Co. has also been making slag Portland cement since 1899, and its manufacture was carried on, in a small way at the Clinton furnace in this city for several years, but has now been abandoned.

The only attempt to make slag bricks in this country, of which I have knowledge, was by the Brier Hill Iron and Coal Co., at Youngstown, Ohio, in 1902, when they erected an experimental plant and produced about 50,000 like the sample here shown.

At Freesland, near Philadelphia, and at Reading, Pa., there are plants for crushing and sizing hard slag for concrete aggregate, roofing, etc.

In the east, gravel for tar roofing has been almost wholly superseded by crushed slag, and it is being shipped from Philadelphia and Reading to Pittsburg, at a cost for freight of more than $2 per ton. Carrying coals to New Castle is a reasonable proposition compared with this.

As a rule limestone is to be preferred for aggregate in foundations, retaining walls, etc., but in concrete floors and walls and other places where weight is an objection, and fire-proof qualities desirable, crushed hard slag is much to be preferred.

If blast-furnace slag were used for all purposes for which it is economical as being better adapted or cheaper than like materials now in use, the order of quantities used would be for the purposes as follows:

First. As sand for concrete street paving, building block, rubble masonry.

Second. In brick; for foundations; superstructure and refractory purposes.

Third. As aggregate for concrete; roofing, etc.

Fourth. In the manufacture of Portland cement.

Fifth. In the manufacture of Pozzuolani cement.

Sixth. In the manufacture of slag wool for non-conducting purposes.

The value of the products for a unit of weight would be in about the reverse of this order.

THE HOT-BLAST TEMPERATURE EQUALIZER*

THE hot-blast temperature equalizer is the invention of Gjers and Harrison, of Middlesborough, England, whose representative in this country is E. A. Uehling, 135 Broadway, New York. It consists of a shell constructed of steel plates similar to that of a hot-blast stove of the Siemens-Cowper type. This shell is filled with fire-brick checker work, preferably with a partition

* "The Iron Age," May 19, 1904.

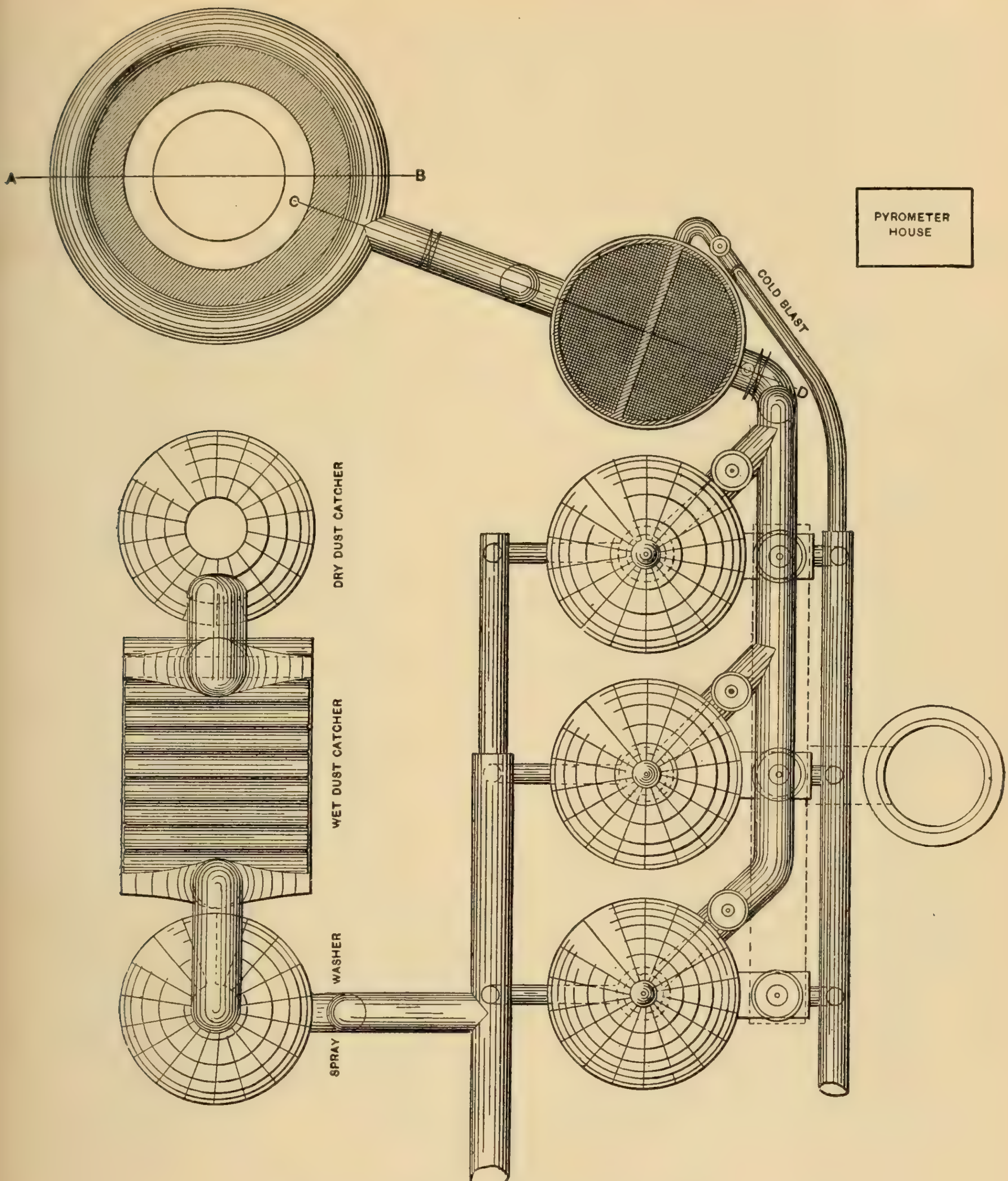

Fig. 1. Plan of Furnace and Equalizer.

wall through the center, as shown in Fig. 2. It is located between the stoves and the blast-furnace which it serves, as shown in Fig. 1, and is so connected that all the blast heated by the stoves in their regular turn passes through the equalizer before entering the bustle pipe.

The checker work is supported on piers, as is usual in stove

construction. Provision is made against loss from radiation by inserting about four inches of insulating material between the shell and the wall encircling the checker work at the bottom and over the top arch. Slag wool answers well for this purpose. The bottom of both sides of the equalizer is made with a sloping

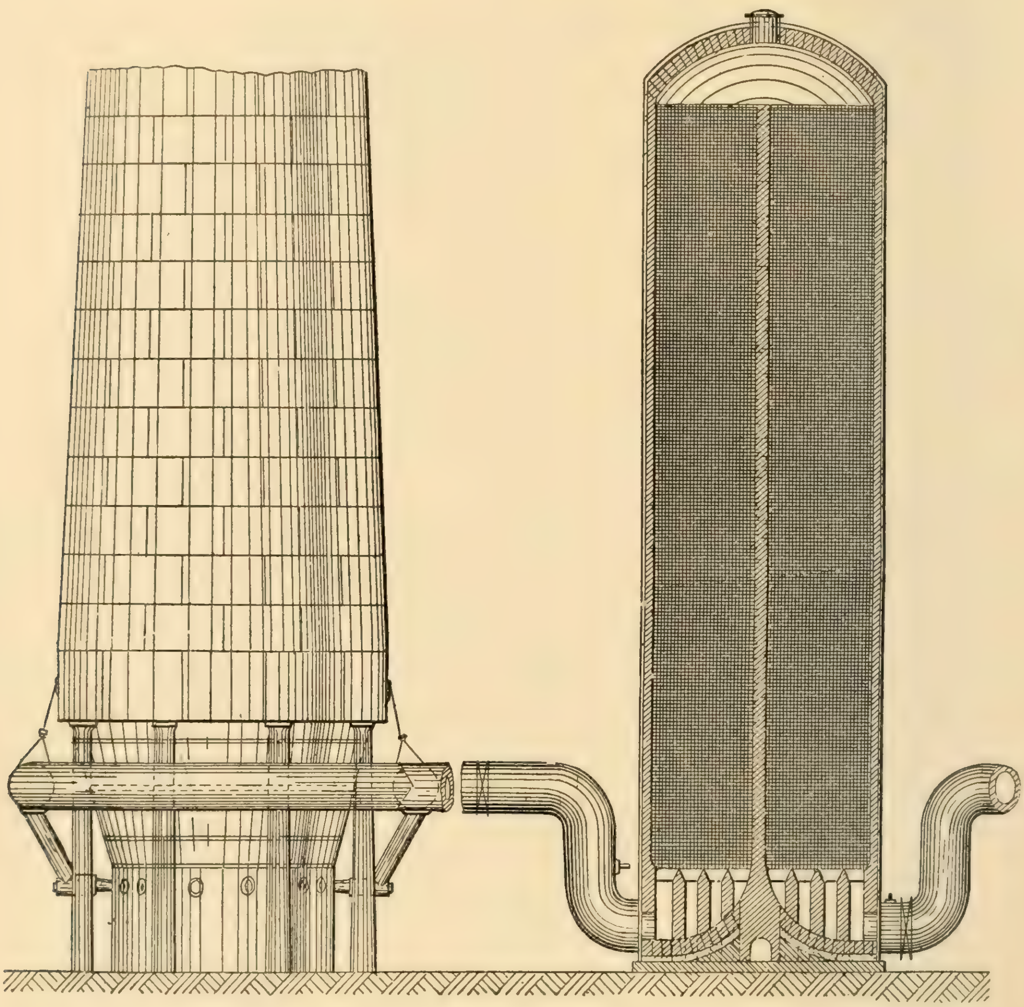

Fig. 2. The Gjers & Harrison Equalizer.

curvature for the purpose of reducing the space under the checker work. In the concrete filling or brick work supporting the partition wall is located a flue connected with the cold-blast main from the outside, and by suitable ducts also with the exit chamber, for the purpose of reducing the temperature of the blast to any degree below that of the equalizer, if desirable. By means of

the cold-blast valve located conveniently to the pyrometer house, the temperature of the blast can be quickly regulated between the limits of the heat stored in the equalizer and that of the cold blast, according to the requirements of the furnace.

The arrangement of setting of stoves and equalizer will vary more or less in every case; that herewith illustrated is the simplest and most direct possible. A bypass may be arranged so that the equalizer can be cut out at any time if anything should go wrong with it. But since the construction is so simple, and its functions are entirely static, a contingency that would put it out of order is so remote that a bypass becomes quite unnecessary and would prove a useless expenditure. There is no mechanism connected with the equalizer, except the cold-blast regulating valve. The checker work is never subjected to a temperature sufficiently high to prejudicially affect the brick. The only dust which can enter the equalizer is that which may be carried away by the blast from the accumulations in the stoves, which being in the swirl of the blast will be carried through the equalizer into the furnace. There is, therefore, no reason why the equalizer should ever get out of order.

The heated blast enters the equalizer through the hot-blast main direct from the stoves near the bottom on one side, passes up through the checker work into the dome-shaped space above, and down through the checker work in the opposite side of the central partition wall and out near the bottom on the opposite side, through the connecting main into the bustle pipe. So long as the temperature of the checker brick in the equalizer is lower than that of the entering blast they will continue to absorb heat. In a short time, however, they will have attained the average temperature of the blast throughout, after which the equalizer will perform its function regularly and continuously so long as the stoves supply the total quantity of heat required.

When a fresh stove is put on, the excess of temperature, above the average, is absorbed in passing through the equalizer and retained until the heat of the entering blast begins to fall below the average, when it is again given out, bringing the blast temperature up to the average. In an equalizer of proper size and proportion the ordinary temperature differences of 150° and 250° should be equalized in passing through the first half of the checker work, leaving the second half as a reserve for

taking care of abnormal temperature differences, and to serve as a reservoir of heat. With clean gas there is no difficulty in carrying from 1,300° to 1,500° of heat on the stoves or an average of 1,400° in the equalizer. By means of the cold blast this may be tempered down to anything the furnace may require. Under normal running conditions the maximum even temperature of blast, suitable to height of furnace and kind of raw material smelted, is most conducive to best economy; but at the same time there should be a reserve of 150° to 200°, and the temperature of blast should be under control; the greater the range of control the better.

A furnace working stiff, or hanging up, may generally be brought down by reducing the blast temperature, but after it has come down it may require the highest available heat to neutralize the chilling effect due to slipping. The equalizer stores up heat for such contingencies, and is, therefore, useful in two distinct and most important functions: 1, as an equalizer of blast temperature; and, 2, as a reservoir of heat.

The one drawback to the regenerative hot-blast stove is the variation of blast temperature, which is rarely less than 200°, and not infrequently reaches 300° (see temperature record, AA, Fig. 3) in an hour's blowing. Such temperature changes may be and frequently are the cause of scaffolding in a furnace, the effects of which on fuel consumption and on reduction of quantity as well as quality of product are always costly, and may become very serious. This fact is fully recognized by every blast-furnace manager, and at the majority of furnaces, which are properly equipped with pyrometers for measuring and recording the temperatures so that he can work intelligently, it is the established practice to equalize the temperature by the admission of cold blast, and by close attention this can be accomplished with fair success (see BB, Fig. 3).

It is evident, however, that since the temperature of the blast coming from the stove is constantly changing, the amount of cold blast introduced for equalization must change in a similar manner. The kinks in the records show that the cold-blast valve was manipulated about every five minutes. At some plants a boy is detailed whose sole duty it is to watch the pyrometer and manipulate the cold-blast valve.

To avoid the necessity of personal attention to the cold-blast

valve, Samuel Vaughn, superintendent of blast-furnaces at the Lorain Steel Company, has contrived a very ingenious apparatus by means of which the cold-blast valve is controlled by electric contact, made by the pen rod of the Steinbart recording gauge

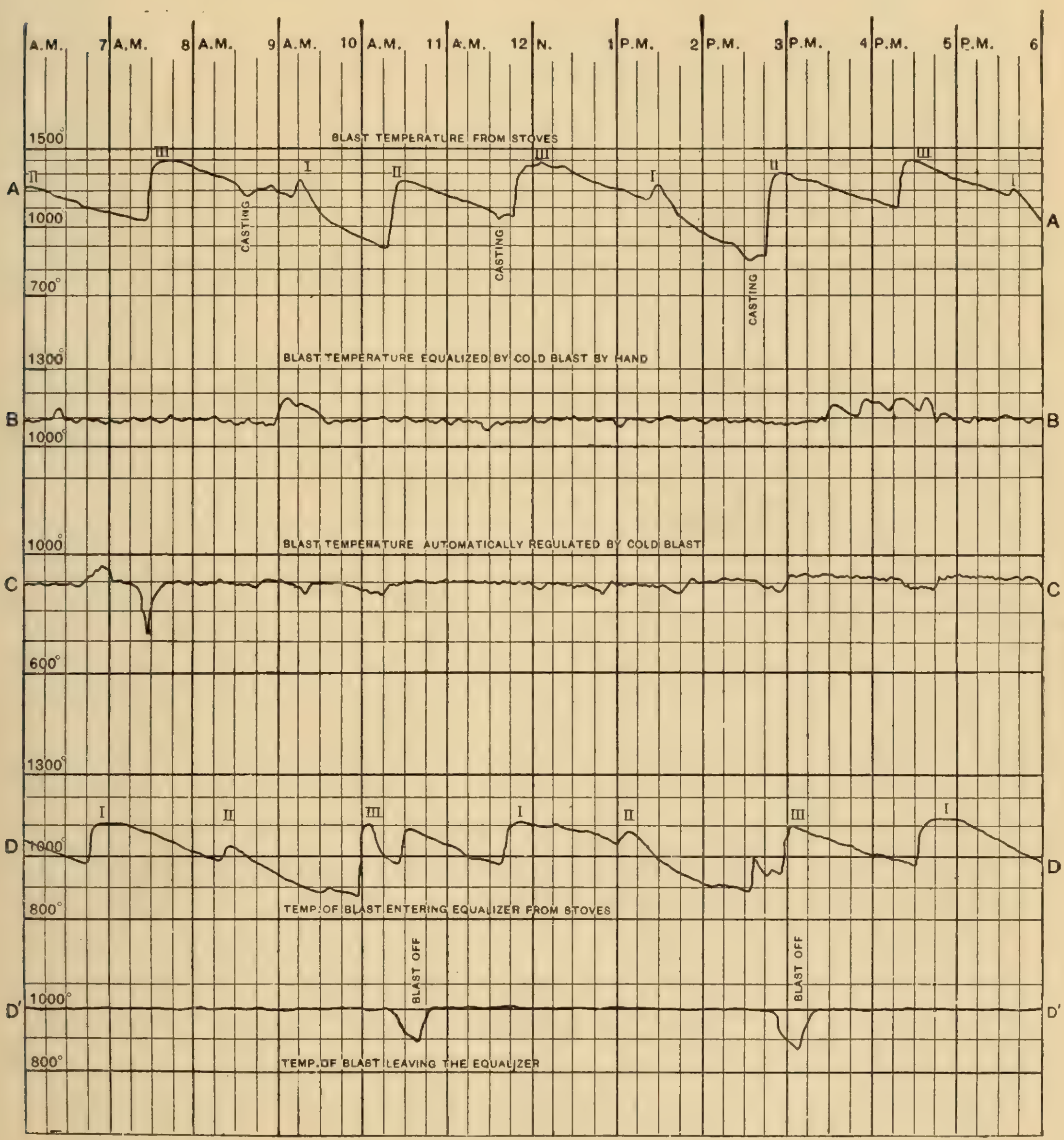

Fig. 3. Autographic Records from the Pneumatic Pyrometer.

used in connection with the pneumatic pyrometer (CC, Fig. 3, shows a temperature record thus regulated).

Where four stoves are available in order to get a more regular blast temperature, the expedient is frequently resorted to

of having two stoves on blast, arranging the time of changing so that the high-temperature period of one stove overlaps the low-temperature period of the other. In this way the variations of temperature may be fairly well equalized by proper attention to the valves. This method, however, requires double the number of stove changes, and since only two stoves are on gas at one time it reduces the heating capacity of a four-stove plant to that of a three-stove one, and accomplishes the purpose in an imperfect manner.

The efforts made to obtain a more regular blast temperature show that furnace managers fully appreciate its value, and the results illustrated show that equalization of blast temperature has been only indifferently accomplished by the more or less troublesome methods applied.

The Gjers and Harrison equalizer accomplishes perfect equalization of temperature with the minimum of attention (see autographic records, DD and D'D', Fig. 3, which were simultaneously taken). The temperature of blast from the equalizer is always the maximum average which the stoves are capable of imparting. By opening or closing the cold-blast valve the heat of the blast may be regulated to any desired temperature of blast below the maximum available; it can be regulated at once, and the required temperature will remain constant without further attention until, in the judgment of the blower or superintendent, the furnace requires a change.

Since the equalizer automatically takes care of all irregularities of temperature, the frequency of changing stoves can in many cases be so regulated that one stoveman will be able to tend two or more sets of stoves instead of one, as is customary at present, or his time may be otherwise usefully employed without affecting the regularity of blast temperature.

The capacity of the equalizer to store heat is a feature of great value. A three-stove plant with an equalizer is very much more efficient than a four-stove plant, and costs appreciably less.

PROFESSOR UNWIN ON TESTING STEEL*

ELSEWHERE in this issue we publish extracts from a paper by Professor Unwin on testing steel. The discussion which took place on this paper showed that it was considered important, as indeed almost anything is bound to be which is put forth by its distinguished author. It is worth noting that Professor Unwin sharply condemns certain practices generally followed here in testing materials and gives his full endorsement to practically all that has been set forth by the advanced Continental testing engineers as being necessary to secure results that can be depended upon. Particularly is this seen in what he has to say about the rate of speed at which tensile test specimens should be pulled and the effect of the inertia of the moving parts of the testing machines in vitiating results when attempting to do the work at too great speed. This vicious practice has been repeatedly condemned here, particularly by one engineer who has made a special study of testing materials, but its importance has been denied or ignored.

It has been said that if there were important pecuniary interests opposed to the law of gravitation, we should have many people denying that law, a voluminous literature attacking it and many people misled and sincerely believing the law to be a humbug and believers in it to be crazy fools. There can be little doubt that important pecuniary interests have had and are now having altogether too much influence upon the determination of the proper methods of testing materials and especially steel. There has been also unfortunately too much of personality in the discussions of these matters here, and, as is well known, our American society of testing engineers withdrew from the international society because the methods advocated here were not approved abroad and are in fact considered to be demonstrably bad. Professor Unwin's strong endorsement of the Continental, or perhaps we should say the German and French, methods and his equally strong condemnation of the methods usually pursued here might well give pause to some of those who have been so cock-sure they were right about all these matters and who would have

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* "American Machinist," July 21, 1904.

others believe, as some of them appear themselves to believe, that they are perfectly unbiased and sincere.

The importance that the matter of testing may assume is shown in connection with the recent failure of the "Iowa's" guns. The forgings for these guns were rejected by a naval inspector stationed at the works where they were made. They were accepted over his head, but at a reduced price on account of small defects which, it was declared, were not important. Sent to the Washington naval gun factory, they were again rejected by the authorities there as being unfit for use and finally were accepted by a specially appointed naval commission, composed of eminent officers it is true, but none of whom could claim any special familiarity with the subject — to put it mildly. The guns have proven their liability to burst and kill people when loaded as they were designed to be loaded, and it seems a clear case of a strong pecuniary interest prevailing against well established physical laws. So far as we know, there is no evidence of gross corruption in connection with the matter, but at least it looks bad, taking the whole story together, and nobody knows how many failures of rails, axles, bridges, etc., have taken place that would not have taken place at all if the material supplied had been proven by rigid and thoroughly scientific tests to be what was contracted for.

The public has a right to expect that engineers will, so far as possible, protect it from accidents due to failure of parts of important structures. We hope never to see the time when it will be proven that lives have been lost that would not have been lost if well-known and better methods of testing had been enforced by engineers who had had every opportunity to become acquainted with such improved methods but had not employed them. Professor Unwin's paper, to say nothing of much else that is on record, will stand as a terribly severe indictment of such engineers, and prejudices aroused by personal animosities will then be no excuse.

ABSTRACTS *

(*From Recent Articles of Interest to the Iron and Steel Metallurgist*)

Effects of Annealing on Steel Rails. Thomas Andrews and C. R. Andrews. "Proceedings of the Institution of Civil Engineers," Vol. CLVI. 8,000 w., illustrated. — The authors describe some experiments dealing with the annealing of steel rails. From their results they draw the following conclusions:

"(1) There would appear to be considerable difficulties, both financial and practical, in annealing the whole of the large output of steel rails in the finished state, and in many instances the outlay and trouble might not perhaps adequately compensate for the possible advantages gained.

"(2) The various sets of experiments in this research have shown that, with medium-carbon and medium-manganese steel rails, the effect of annealing at any of the three temperatures employed (770° C., 850° C. and 940° C.) has been beneficial to the general physical properties of rails of this type, although it may be remarked that the maximum strength of those annealed at the highest temperature (940° C.) had rather fallen below the minimum desirable for rail service.

"(3) If, however, the practical difficulties of annealing large quantities of finished rails could be overcome, it would appear from the other portions of these experiments that the annealing, at any of the temperatures employed, had improved

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* Note. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

the physical properties of the high-carbon and high-manganese series of rails, by bringing their maximum strength more into consonance with the best requirements for durability and safe service, and at the same time by increasing their ductility. Such rails would therefore consequently be less liable to sudden fracture after annealing than before it. Annealing, if practical on the large scale, would therefore offer advantages in the case of rails of the high-carbon and high-manganese type, provided the annealing were not excessive. It may, however, be observed that similar satisfactory physical qualities may be secured without the expense of annealing, by keeping the chemical composition of the finished rail within the limits of the analyses of medium-carbon and medium-manganese steel rails given in Appendixes I, II and III, and by proper attention to temperature conditions during manipulation.

" (4) An important factor to be considered in the question of annealing steel rails is the loss in weight and size from the oxidation or scaling during the process, which the experiments of this investigation have shown to be considerable, Appendix IV. From this cause alone the cost of the permanent-way would be materially increased, in addition to the actual cost of the annealing. A practical objection to annealing the finished rail would be the difficulty of keeping the rail straight, and it is to be feared that many of them would be twisted and warped after the process. Further, there would be much expense in cleaning or scaling the whole surface of each rail after annealing. The rails would not be fit to be placed with safety in the permanent-way until this had been done in the case of each rail, as the thickness of the scale from effectual annealing is a considerable quantity to be reckoned with. The loss in mass strength from scaling is also indicated by the reduced dimensions of the rails after annealing, so that an enlarged section would be needed to allow for such loss of dimensions. Pending further light on the subject it does not at present appear to be clear that any great practical advantage would accrue from attempting the wholesale annealing of finished steel rails, although in some special cases there may perhaps be exceptions. Careful attention to the physical composition of the finished rails, and to their thermal treatment

during manipulation, will go far to ensure a good rail, whether of acid-Bessemer or acid-Siemens steel, provided that the chemical composition is in reasonable practical accord with the type of medium-carbon and medium-manganese rails given in Appendixes I, II and III, which appear to be best suited to ensure durability and safety.

"(5) The annealing at the lower temperatures of 770° C., and 850° C., affected the maximum strength and elongation, and also the elastic limit to some extent, both of the medium-carbon and medium-manganese steel rails, and of the high-carbon and high-manganese steel rails; but on annealing at the highest temperature, (940° C.), although the maximum strength and elongation were influenced, the elastic limit of both types of rails was comparatively little affected by the annealing at the latter temperature. The effect on the maximum strength and elongation of the high-carbon and high-manganese steel rails was marked, as is shown by the results given in Appendixes I, II and III.

"The foregoing remarks apply exclusively to the annealing of finished rails in bulk. If it is considered advantageous to anneal rails, this might probably be done with less difficulty and expense by annealing the ingots, under proper and effectual thermal conditions, or by allowing them to become quite cold before reheating them for the final rolling. This method might probably somewhat more easily accomplish the object in view, viz., to ensure a more uniform micro-crystalline structure throughout the bulk of the rails, and also to promote greater uniformity in the general physical properties. Practical experiments on the large scale to determine this are being undertaken. It also remains to be decided, by further practical experiment, whether the increased expense and trouble involved in annealing rails would be compensated for by a corresponding advantage of increased durability and safety in actual practice on the permanent-way." **No. 200.**

Chemical Classification and its Application to the Constituents of Steel. Professor H. Le Chatelier. "Revue de Métallurgie," Vol. I, No. 4. 10,000 w., illustrated. — The study of alloys presents no little difficulty in that individual crystals of different species of homogeneous matters, definite

compounds or solutions, are often exceedingly minute, and at times even so small as to escape the resolving powers of the most powerful microscope. On the other hand, the study of natural rocks is more favorably placed, in that the constituent crystals are larger and occasionally visible to unaided vision. With metallic alloys, particularly those of iron, similar conditions do not exist, and a classification of constituents which do not permit of isolation has to be made. The difficulties thus presented are intensified by the multiplication of methods; thus, in combining the microscopical examination after attack with various etching mediums, with measurements of electrical resistance, dilatation, absorption of latent heat, etc. Commencing with pure iron, which microscopically presents a series of grains of no definite geometrical contour, Osmond has shown that it may exist in different allotropic states. For instance, at 900° C. he proves a transformation characterized by the absorption of latent heat, by a sharp contraction, by changes in the laws of thermo-electric force, and electric conductivity, and by a sharp, but less marked, change in the magnetic properties. A further transformation is found at 750° C., but of a nature quite distinct from that occurring at 900°. After iron the second essential constituent of steel is carbon, which is known under three allotropic states of diamond, graphite, and amorphous carbon. In the alloys of iron the variety graphite only is met with. A definite carbide of iron F_3C or "cementite" is formed by the association of iron with carbon, and this compound forms the major part of white cast iron. Iron possesses the property of forming solid solutions with many substances, occasionally in all proportions, as with manganese and nickel, and with others to a limited extent only, as with phosphorus up to one per cent and silicon up to 15 per cent. Iron containing in solid solution slight traces of these substances constitutes the phase "pure iron" in ordinary iron and steels which are always slightly impure. This phase is termed "ferrite." In a similar manner cementite can mix isomorphically with the carbide of manganese Mn_3C. These features illustrate in the case of iron the difficulties already noted. Carbon yields with iron solid solutions of great metallurgical importance, but of very difficult study. These solid solutions are only normally stable at tem-

peratures superior to 700° C., and they may only be preserved in an incomplete manner at ordinary temperatures by rapid cooling. Solid solutions of iron and carbon possess when fluid all the properties of liquid solutions, and the carbon diffuses like salts in their aqueous solutions. These solutions present the phenomenon of saturation — they deposit by cooling as the case may be, ferrite, cementite, or even graphite. The curves of solubility determined by Osmond and Roberts-Austen show that the addition to pure iron of an increasing content of carbon gradually lowers the transformation point until with 0.9 per cent carbon it is lowered from the normal one of 900° C. to 700°. This temperature of 700° C., known as the recalescence, corresponds to the eutectic point of the alloys of minimum fusion. The solidification of this eutectic gives simultaneously alternate plates of iron and cementite, termed "pearlite." The classification of the constituents of quenched steels cannot be considered definite. The first supposition leads to the conclusion that the effect of quenching is to preserve at ordinary temperatures a normal stable variety of the high temperatures. With hardened steels, however, this is not the case; for, though their condition is entirely distinct from the stable cold state, it is, nevertheless, a condition not absolutely identical with that existing at the high temperatures. For instance, steel at high temperatures is no more magnetic than the variety of pure iron stable above 900°, yet quenched steels are very magnetic and are employed in the construction of magnets. Further, a single variety is not obtained by quenching, but several constituents may be obtained by modifying the quenching temperature or varying the content of carbon. The study of these quenched steels is difficult, owing to the impossibility of isolating the constituents in order to examine their individual properties. Thus one section may contain several constituents, and the only method by which they may be studied is the microscopical examination of polished and etched surfaces. The most familiar etching mediums employed in differentiating the constituents of quenched steels are solutions in absolute alcohol of azotic, hydrochloric, or picric acids. Osmond has distinguished in these steels three constituents, termed respectively "troostite," "martensite," and "austenite." In steels

rapidly cooled, but not actually quenched, or in quenched steels lightly annealed, a fourth constituent ("sorbite") is found. Troostite is most familiar as a dark border separating pearlite and martensite, and may be obtained by quenching steels in the middle of their transformation or about 750° C. Martensite is obtained by quenching steels of variable composition (0.3 to 1.3 per cent carbon) from above the recalescence point. A steel of 1.4 per cent carbon quenched from 1,200° C. and etched with picric acid in alcoholic solution presents austenite. The differentiation of these three constituents rests solely on differences of feeble attack by the etching medium employed. "The Engineering Review," July, 1904. **No. 201. H.**

Direct Casting from the Blast-Furnace. "The Engineer," July 1, 1904. 2,000 w. — The article describes a plant recently built by the Northamptonshire Direct Iron Casting Co., for the making of iron castings directly from the blast-furnace. The works include four 50-foot blast-furnaces and the usual appliances of a foundry. The present output is about 100 tons of castings per week. **No. 203. A.**

A New Chuck for Short Test Pieces. T. D. Lynch. A paper read at the Atlantic City meeting of the American Society for Testing Materials. 1,000 w., illustrated. "The Iron Trade Review," July 7, 1904. **No. 204. A.**

The Tod Rolling-Mill Engines. "The Iron Age," July 28, 1904. 5,000 w., illustrated. — The author describes and illustrates some modern engines built by the William Tod Company, of Youngstown, Ohio. **No. 205. A.**

Bending Moments in Rails. Extract from a paper by P. H. Dudley, read at the Atlantic City meeting of the American Society for Testing Materials, June, 1904. "The Railroad Gazette," July 15, 1904. **No. 208. A.**

Tungsten Steels. Léon Guillet. "Revue de Métallurgie." 5,000 w., illustrated. — Two series of steels of ascending content of tungsten have been examined, the first series being comparatively low in carbon, whilst the second one

contains approximately 0.8 per cent. The actual amount of carbon and tungsten present are given in the accompanying table, together with the results obtained from tensile, shock, and hardness tests:

Series I

Carbon Per Cent	Tungsten Per Cent	Elastic Limit	Maximum Stress	Elongation Per Cent	Frémont Test: Kilogrammeters	Hardness Brinell's
0.117	0.412	30.1	41.1	19	25	97
0.113	0.939	31.6	42.1	18	29	97
0.110	1.750	37.6	48.9	18	26	109
0.126	4.965	33.9	63.2	13.5	20	153
0.176	11.890	79.1	86.6	5	6	223
0.201	14.270	54.6	77.2	10.5	5	167
0.221	20.710	48.9	71.5	9	4	163
0.219	24.350	41.4	60.2	4	6	187
0.276	27.750	56.4	67.0	2.5	6	217

Series II

Carbon Per Cent	Tungsten Per Cent	Elastic Limit	Maximum Stress	Elongation Per Cent	Frémont Test: Kilogrammeters	Hardness Brinell's
0.861	0.397	56.4	103.2	6.0	1	241
0.852	0.951	62.8	113.0	5.5	1	241
0.795	2.750	75.3	124.3	5.5	1	302
0.823	4.676	85.8	126.5	5	5	302
0.815	9.991	101.7	134.8	3.5	4	293
0.715	14.739	67.8	129.9	2	5	351
0.797	19.250	71.5	105.4	3.5	6	277
0.743	25.270	94.1	113.0	0.5	6	351

"The Engineering Review," July, 1904. **No. 202. H.**

Hot Blast Regulation. J. J. Stevenson. "The Iron and Coal Trades Review," July 8, 1904. 1,000 w. — The author describes an instrument manufactured by Baird and Tatlock of of Glasgow, for registering and automatically regulating the temperature of the blast. **No. 206. A.**

Pig-Iron Feasts and Famines. Extract from a paper read by Geo. H. Hall at the Atlantic City meeting of the American Society for Testing Materials, June, 1904. "The Railroad Gazette," July 15, 1904. **No. 207. A.**

Lubrication of Steel Works and Blast-Furnace Engines. William M. Davis. "The Engineer" (Chicago), July 15, 1904. 2,000 w. **No. 209. A.**

Machine Molding. C. P. Campbell. "The American Machinist," July 28, 1904. 2,250 w. **No. 210. A.**

"The Foundry." — The August (1904) issue of "The Foundry" contains the following articles of interest:

"Core Crush, Its Cause and Remedy." William Leary.

"Education of Foundrymen." Editorial.

"Standard Methods for Making Beds." Thos. D. West. (Paper read at the A. F. A. Convention, Indianapolis, June, 1904.)

"Molding Machine Practice." F. W. Hall. **No. 211. A.**

Metallography. O. Bauer. — Mr. Bauer takes exception to the abstract which was published in the May issue of *The Iron and Steel Magazine* of his paper on "Metallography," which appeared in the issues of January 1 and 15 of "Baumaterialkunde." He writes that he did not refer to Charpy, Le Chatelier, Jüptner, Standsfield, Heycock, Neville and Cartaud as "less important" metallographists. On the contrary, he wanted to emphasize the important work of Le Chatelier, without whose pyrometer metallography could hardly have progressed. Martens, Osmond, and Roberts-Austen are hardly mentioned in the abstract, contrary to the contents of the text, while the work of Arnold, Howe, Andrews, and Sauveur is given too much prominence. Mr. Bauer's objections were submitted to our German translator, who claims that, although making a very free abstract of the paper, he had retained the substance of it.

EDITORIAL COMMENT

Hans Freiherr v. Jüptner

Hans Freiherr v. Jüptner, whose photograph will be found reproduced as a frontispiece to the present issue of *The Iron and Steel Magazine,* was born in Vienna May 22, 1853. From 1863 to 1874 he attended school in his native city, graduating in the latter year from the Royal Technical College. After the completion of his technical studies he served as assistant at the Royal Geological Laboratory, and from 1877 to 1882 he was connected with the Royal Engraving offices. In 1882 he was appointed head chemist of the Austrian Alpine Mining Co. in Newburg, Steiermark, and in 1898 was made chief engineer and chemist at the Donawitz works of the same company. In 1896 Professor v. Jüptner was offered the professorship of metallurgy in the University of Tokio, Japan, but declined it. In 1902 he was appointed professor of chemical technology in the Royal Technical College at Vienna, a position which he still holds. It will be remembered that Professor v. Jüptner was selected for the directorship of the proposed Sidero-Chemical Laboratory of the International Association for the Testing of Materials, an undertaking which has since been abandoned. Professor v. Jüptner has held several positions on committees appointed by various technical societies. The subject of this sketch has written many important papers dealing with the advanced study of iron and steel, nine of which were published in the "Journal of the Iron and Steel Institute." He has also written several well-known books, among which should be especially mentioned a "Practical Handbook of Metallurgical Chemistry," which has been translated into French, his three volumes on "Principles of Siderology," the first of which has been translated into English, a text-book on physical chemistry, etc. Professor v. Jüptner's writings entitle him to a leading position as a profound student of metallurgical science.

Self-Hardening Steel vs. High-Speed Steel

In a paper on "Alloy Steels," read by Mr. Wm. Metcalf at the Atlantic City meeting of the American Society for the Testing of Materials, and reproduced in the August issue of *The Iron and Steel Magazine,* the author would draw a sharp distinction between ordinary self-hardening or Mushet steel and those special steels now known as high-speed steels. "The present high-speed steels," the author writes, "are in no sense of the word air-hardening." And we find this opinion shared by other metallurgists and engineers. To us it seems, however, that no such distinction can be made between these two varieties of steels. Mr. Metcalf himself tells us that the discovery of high-speed steel resulted from the overheating (possibly accidental) of some ordinary self-hardening steel. This treatment, which had hitherto been considered ruinous when applied to self-hardening steel, resulted in imparting to it those wonderful high-speed qualities now so well known to our readers. By this treatment the self-hardening steel was converted into a high-speed steel. We want no more conclusive evidence of the fact that no sharp demarcation can be drawn between self-hardening and high-speed steel. It may be that, as at present manufactured, the high-speed steel differs materially in composition from Mushet self-hardening steel. It may be that the proportion of tungsten has been increased and that of manganese lowered, or that in some brands the tungsten has been replaced by molybdenum. The fact remains, nevertheless, that, to all tungsten steels of the self-hardening variety, if properly treated, high-speed qualities may be imparted. By altering the composition as pointed out above, these high-speed qualities may be intensified, but the difference between the two varieties of steels remains at best one of degree, not of kind.

IRON AND STEEL METALLURGICAL NOTES

The Field of the Steel Foundry. — "The Journal of the American Foundrymen's Association" said in a recent issue:

"A veritable fever for establishing Baby-Bessemer plants seems to be raging in Europe at the present time. It is as if a microbe had bitten many gray iron and malleable founders, and caused them to add these plants to their establishments and thus enter into fierce competition with existing steel foundries. The results are natural. Failure everywhere. The idea of Bessemerizing iron to make steel was only perfected by its illustrious author by the application of science and consummate skill. Others had failed to get his results while trying his methods. They missed the little points. So here also. The Baby-Bessemer process in itself is all right, but must be carried out with even more skill than is required for its big brother, otherwise commercial failure is certain to result."

There has been some of the same failure and disappointment in the United States, but these experiences have been of value in making others doubly sure of their ground before entering an untried field. Some excellent results have been attained where the proposition was approached with the proper outfit of experience and the proper appreciation of the limitations of the small Bessemer converter. There have been failures, too, in the malleable field and in steel casting manufacture where the expensive open-hearth outfit was employed. In fact, there has been shown by some companies that have essayed these lines a fatuous confidence that large profits were to be had for the entering in and taking. The allurements of metallurgical operations in general have been sufficient to tempt many incompetent and inexperienced investors, who recklessly underestimated the necessity of expert service. The

foundry industry in all its departments is conspicuous for the failures that have come to men who have been driven in by covetousness of the profits made by a few. The importance of management as the great factor in earnings, exceeding local advantages, proximity of markets, connection with consuming interests and a dozen other elements ordinarily cited as sure to bring success, is wofully underestimated.

The caution quoted above is timely. So far as the steel-casting industry is concerned, whatever the process, the ranks are now fairly well crowded and promise to be so for some time to come. "The Iron Trade Review," July 14, 1904.

Heavy Rails Laid in Philadelphia. — The Pennsylvania Railroad completed last week three tracks built of the heaviest rail used in the history of railroading. They are the Delaware avenue freight lines in Philadelphia, and were constructed for the use of the Belt Line, the Reading and the Pennsylvania roads, each of which was assessed one-third of the cost. The tracks extend from Race street to Washington avenue, and are intended to accommodate the fruit and produce commission merchants, as well as the heavier shippers of the city. The rails weigh 142 pounds to the yard, and are by 17 pounds heavier than any before used. They are ballasted in concrete and nine-inch girders were used to bind them. All the curves and spurs were made of the same heavy rails, and the tracks are considered superior to any railroad section ever undertaken. The rails were made especially for the Pennsylvania railroad by the Pennsylvania Steel Co. An officer of the railroad said that this section of roadbed will last for twenty-five years without repairs. It required three months to place the rails, and the whole street has been paved with granite blocks. "The Iron Trade Review," July 14, 1904.

Rail Testing. — At present three series of tests for rails are used. Tensile tests are made to measure the strength and ductility of the steel; bending tests to secure a high elastic limit; and impact tests to insure that the metal shall not be brittle. The impact test — in theory, at least — is of capital importance; for if the metal is too soft, the rail will deform more or less rapidly; but if its resistance to impact is insuffi-

cient, the rail may break in use. In fact, cases have been known in which rails have broken merely in transport. As generally applied, however, the conditions of the impact test are drawn up on the assumption that the rails are homogeneous. A maximum deflection is provided for, and the weight of the tup and the height of the fall fixed so that a good rail will not be broken by the test. In practice, rails are often not homogeneous, and, consequently, rails which will pass the ordinary impact test, sometimes fail later under traffic. This lack of uniformity in the rail material is sometimes due to the piped portion of the ingot not being entirely removed, in which case the center of the rail will be unsound, and suffer from segregation of its constituents. Such a rail may, hovever, resist the ordinary impact test very well, because its exterior surfaces are of good steel, but owing to the vibrations arising in service, cracks are liable to start in the unsound portion of the rail, and to spread ultimately into the good metal. Another cause of lack of uniformity in rails arises from the heat treatment and mechanical treatment to which they are subjected in the process of manufacture, which may be such as to leave the center of the rail brittle, whilst the rest remains ductile. The bad metal being thus generally in the interior of the rail, it has been proposed to concentrate on this portion the tests made. Pieces of rail about 20 inches long are taken. In the head of these a notch is cut near the center of its length 2.4 inches long, the ends of which are rounded off to a radius of 0.59 inches. This notch extends half way through the head. The specimens thus prepared are placed on hardened steel supports 15.74 inches apart. These supports are of semi-circular section, the diameter being 0.55 inch. The bar is then tested in impact with the notch below. The tup falls a height of four meters, and is of sufficient weight to break even the best quality of rail. After fracture the two broken ends are placed together, and the quality of the metal is then shown by the amount the rail has deflected before rupture. With rails of good quality this deflection will range from 0.23 inch up to 0.78 inch, whilst with other rails the deflection is so small as to be unmeasurable. As only small portions of rail are broken in this test, it is claimed that it is cheaper than the usual one. "Engineering," July 15, 1904.

The Price of Mesabi Ores. — Two years ago, when negotiations were pending for the sale of what are known as Hill lands on the Mesabi iron range, it was given out that Mr. Hill based his selling price on a valuation of $1 per ton for iron ore in the ground. Even in the boom times, that looked like a high price; at present, it looks much higher. Mesabi Bessemer ores are selling this season at $3 per ton at Lake Erie docks, while Mesabi non-Bessemers have sold as low as $2.40. From these prices are to be deducted the lake freight of 70 cents, dock charges and the rail freight from the mine to Duluth or Superior, so that the operator does not receive over $1.30 to $1.35 for Bessemer ores, and 70 to 75 cents for non-Bessemers, out of which must come the cost of mining. As nearly all Mesabi mines are charged with royalties varying from 25 to 50 cents per ton to the fee-owners, the margin for profit to operators who sell their ore does not look large. "Engineering and Mining Journal," July 21, 1904.

Exports of Iron Ores. — Exports of iron ore from the United States in recent years have been confined, practically, to shipments of Lake Superior ore to a few Canadian furnaces. No ore has been sent to Europe, except a few small lots for experimental purposes. Recently, however, a beginning has been made by the export of a considerable quantity of ore to Glasgow and Antwerp; 12,000 tons having been sent in June, while it is understood that 18,000 tons more will follow, the present contracts covering a total of 30,000 tons. This ore is shipped by Witherbee, Sherman & Company, and is from the mines owned by that company, in the Lake Champlain district in New York. The ore is carried from Port Henry by lake and canal to New York harbor. The movement has been favored by low ocean rates, the charge from New York to Antwerp being about 5 shillings, or $1.20 per ton. It is understood that negotiations are pending for further sales abroad. "Engineering and Mining Journal," July 14, 1904.

Purification of Blast-Furnace Gases. — One of the most important problems at present demanding consideration in connection with blast-furnace practice is the purification of

the gas coming from the furnaces. It is a fact, pointed out by Mr. E. A. Uehling recently before the American Institute of Mining Engineers, that with but few exceptions, the gas of the modern blast-furnace carries more dirt into the stoves and under the boilers to-day than was the case a quarter of a century ago. It is true the dust-catchers have been increased in size and dust-pockets have been multiplied, but the subject has not received attention that its importance demands. It has been entirely overlooked that, with clean gas, the heating surface of every hot-blast stove could be doubled and the steaming capacity of every boiler increased at least from 30 to 50 per cent, and that the capital now being invested in additional stoves and more boilers, which the heavy repairs and frequent stoppages, caused by dirty gas, make necessary, would in most cases be more than sufficient to install an efficient washing plant. There is no improvement that could be suggested in connection with the modern blast-furnace that would yield a greater return from the investment than an efficient gas-washing plant, except the blast-furnace gas engine, and this latter must necessarily be served with clean gas. "Cassier's Magazine," July 1, 1904.

The Jones & Laughlin Steel Company. — Some excellent records for production have been made recently in the Talbot open-hearth furnace in the American Iron and Steel Works of the Jones & Laughlin Steel Company, Pittsburg. The quantity of steel turned out has been so large — amounting to 1,600 to 1,800 tons per week — and the quality so satisfactory that the company has decided to build three more Talbot furnaces, and possibly four, of the same size as the present one. Work has already been started on one of these furnaces. The company is also installing 21 soaking pits in its steel department, as it has been short of heating capacity for some time. To provide room for these soaking pits, a continuous bar mill, known as mill No. 45, is being removed to another part of the plant. The company is now operating its entire plant to nearly full capacity. "Iron Age," July 28, 1904.

The Rusting of Iron. — W. R. Dunstan publishes in the "Proceedings of the Chemical Society" a summary of the present

results of an unfinished inquiry into the reactions involved in the rusting of iron. While both liquid water and oxygen are necessary for the formation of rust, the presence of carbonic acid is not essential, although it may accelerate the action. The well-known effect of alkalies and alkaline salts in preventing oxidation of iron has been hitherto attributed to the withdrawal of the carbonic acid. It has been found, however, that the phenomenon is not due to this cause, but to the establishment of conditions in which the production of hydrogen peroxide is inhibited. When highly purified iron, containing mere traces of impurity, is left in contact with dry gases (oxygen, carbon dioxide, mixtures of oxygen and carbon dioxide), rusting does not take place. In the presence of the same gases and water vapor, no rusting occurs so long as a constant temperature (34° in the actual experiments) is maintained; but if the temperature is allowed to fluctuate, liquid water condenses on the surface of the iron and rust is produced. It is thus shown that pure iron is not oxidized in presence of gases and water vapor only, but that the presence of liquid water is necessary for rusting to take place. In another series of experiments pieces of iron were left in contact with water saturated with a particular gas and with an atmosphere of the same gas above the solution. When hydrogen, carbon dioxide or nitrogen which had been carefully freed from oxygen was employed, rusting did not occur, but if oxygen or a mixture of oxygen and carbon dioxide was used, oxidation took place. From these results, it is evident that for the formation of rust both oxygen and liquid water are required. In the experiments in which a mixture of oxygen and carbon dioxide was used, the results observed indicated that in this case a secondary action proceeds simultaneously. "The Journal of the Franklin Institute," August, 1904.

REVIEW OF THE IRON AND STEEL MARKET

The whole American iron trade has been shaken during the month of August by several startling developments, including a billet conversion contract which ignored at least the spirit of the price agreement, a heavy cut in wire products, and the appearance of the Lackawanna Steel Company as a seller of plates and structural shapes at less than the pool and association prices.

These events have been variously regarded in the trade. Those who held to the view that there had been a real, though slight, improvement in the situation during July, took the view that the market had received a severe setback, from which it could only gradually recover. Those who held that no genuine improvement could be expected before the beginning of next year, and then would be materially aided by the collapse of an artificial price structure on semi and wholly finished steel products, took the view that the developments were a blessing in disguise, and were to be welcomed as being important steps towards a sound condition. In the glamour of four years of price control during a period of exceptional demand the former view would seem the more tenable; in the light of history, the latter.

On Saturday, July 30, an arrangement was privately made between the Pittsburg Steel Company, which operates rod, wire and hoop mills, and the Republic Iron and Steel Company, whereby the former should furnish the latter 110,000 tons of Bessemer pig iron and receive in return 110,000 tons of Bessemer billets, at a conversion price of approximately $6 per ton, deliveries extending over the ensuing ten months. No freights were included in the conversion price. In the next couple of days the Pittsburg Steel Company closed its pig iron purchases, and the deal was announced on Wednesday, August 3. It created more consternation on the part of other steel makers, and on the part of the general iron and steel trade, than was anticipated. The Bessemer pig iron was bought at $12 at valley furnace, involving freights of from 15 to 35 cents for delivery to the Republic steel

mill at Youngstown, while the freight on the billets from Youngstown to Monessen and Glassport, Pa., where the Pittsburg company's works are located, amounts to 95 cents, so that the billets actually cost the latter between $19 and $19.25, against the $23 price which the billet association has striven to maintain. It should, however, have been well understood that the $23 price could hardly apply to any such large tonnage as was involved in this deal. The news was received by some of the other steel works with public hints that there was very little profit in the transaction, and by private demands on the seller for a division of the tonnage. Indeed, such a division was almost conceded at a conference, when the Republic representative suddenly withdrew and negotiations closed.

The next development was when the Lackawanna Steel Company took a contract in Pittsburg for 3,000 tons of structural shapes, at a price lower than that maintained by the beam pool. The Lackawanna company has almost completed the largest single iron and steel making unit in the world at Buffalo, N. Y., with its own ore docks. It is a member of the rail pool by virtue of having been previously a maker of rails at Scranton, Pa., but does not belong to the beam pool or the plate association. It has been making rails for some time, and will probably commence making plates and shapes within the ensuing month. Membership in the beam pool has been offered it, but the offer has been declined on the double ground that the allotment proposed is insufficient and that the present members of the pool are not adhering to the spirit of the arrangement inasmuch as they themselves operate fabricating plants at no profit, and thus obtain a tonnage by bidding on finished structural work which would be denied Lackawanna through the latter's not yet having fabricating equipment. The advent of so large a new and independent producer of shapes and plates has most seriously menaced the price control heretofore maintained in these lines at 1.60 cents a pound during a period when both pig iron and crude steel have had a large and steady decline.

On Thursday, August 11, the American Steel and Wire Company met three of the four important independent wire makers, and an agreement was reached to maintain wire prices at the then ruling market, which was $2 a ton below the official prices promulgated in March, and held for some time thereafter. On Tuesday, August 16, the American Steel and Wire Company

announced a drastic cut in wire products, $5 per ton on plain wire, $4 on wire nails, and $7 on barb wire. Whether this was in retaliation for the billet conversion deal or for cutting of the newly agreed upon prices by the independents, is a disputed point. The Pittsburg Steel Company rejoined by offering to sell to any carload buyer at the new prices, whereas the custom of the trade had been to make the minimum prices only to large jobbers. Further cutting is therefore far from improbable.

As a result of these occurrences the market is almost at a standstill and the trade is on the *qui vive* for further developments. Meanwhile it is somewhat of a question whether any of the price agreements have any real force, outside of the rail arrangement, which is not so easily disturbed.

Ore. — Some large sales of Lake Superior ores were made early in the month, the total transactions including some made in July exceeding 1,000,000 tons. While the market is technically an open one prices are guaranteed against a decline, and the market has therefore been quite steady. Standard Mesabi Bessemers have ruled at $2.75 to $2.80, f.o.b. lower lake ports, and Mesabi non-Bessemers at $2.25 to $2.35. However, slightly higher prices have been paid for the best quality of Bessemers, while some non-Bessemers have brought as high as $2.65. The average ore now offered in the market is much inferior to those which were freely sold a few years ago.

Pig Iron. — Early in the month the market showed decided strength owing to the placing of further contracts for pig iron for the Pennsylvania tunnel work, the buying of the Pittsburg Steel Company for conversion, and the buying of various small lots by consumers whose previous contracts had run out. There was a barely measurable advance in prices, but this has been wiped out in the stagnation which has followed the developments in the steel trade, and the market for northern iron can now be quoted approximately as follows: Bessemer and No. 2 foundry, $11.90 at valley furnace or $12.75, delivered Pittsburg; forge, $11.75, delivered Pittsburg; basic, $11.75, valley, or $12.60, Pittsburg. Southern iron has been very strong, as the coal strike in Alabama started in July resulted in fully two-thirds of the Alabama furnaces being idle, and there have been few if any sellers at less than $9.50, Birmingham, for No. 2 foundry.

Steel. — The market is too uncertain to warrant any attempt at quoting prices.

STATISTICS

Correction. — In presenting a comparison of coke and anthracite pig iron production for half years in our August number, the total for the first half of this year was credited to Mr. James M. Swank, instead of to "The Iron Age." The figures for the two halves of 1903 were properly credited to Mr. Swank.

American Pig Iron Production. — Complete statistics of production of pig iron in the United States during the first half of 1904 have been presented by Mr. James M. Swank, of the American Iron and Steel Association.

The production compares as follows with two previous half years:

	Tons of 2,240 lbs.
First half, 1903	9,707,367
Second half, 1903	8,301,885
First half, 1904	8,173,438

The production for the first half of 1904 reported by grades is as follows, together with the amount of forge, foundry, etc., necessary to make up the total, obtained by difference:

	Tons of 2,240 lbs.
Bessemer	4,443,364
Basic	1,061,901
Charcoal	213,356
Low Phosphorus	87,582
Ferro-Manganese	26,541
Spiegeleisen	87,665
Ferro-Phosphorus	304
Forge, Foundry, etc.	2,252,725
	8,173,438

RECENT PUBLICATIONS

Thermodynamics and Chemistry, by P. Duhem. Translated into English by G. K. Burgess. 445 9 × 5½-in. pages; 140 illustrations. John Wiley and Sons. New York. 1903. — On the occasion of the original publication of this book, in French, a review of it appeared in the July (1903) issue of *The Metallographist,* from which the following is quoted:

" The present excursions of students of scientific metallurgy in fields which appear to be very foreign to that art, afford a striking instance of the close relation between all physical sciences. Physics and chemistry are no longer regarded as two distinct sciences with sharply drawn boundary lines between them; chemical physics and physical chemistry are words of current use. The supposed gap between mechanics on the one hand and physics and chemistry on the other has been filled by thermodynamics which firmly bind these sciences together. While to the casual observer it must seem as if a fair knowledge of inorganic chemistry and of the fundamental principles of physics constitute all the scientific equipment required to arrive at an intelligent understanding of metallurgical phenomena, the advanced student of metallurgy, at least of the metallurgy of iron, has discovered that it is not sufficient. When he was led to look more closely than had been done by his predecessors into the constitution of steel, he reached the conclusion that this important metal was in reality an alloy of iron and carbon, and this discovery increased his interest in alloys in general, and in the modern theory of these substances which was being so brilliantly worked out. Alloys, in turn, were shown to be, contrary to the prevailing belief, actual solutions of the component metals, from which it followed that steel also was a solution of carbon in iron. The metallurgist now looked into the nature of solutions, into their solubility curves, into the phase rule of Gibbs, this remarkable application of thermody-

namics to chemical phenomena, which in the hands of some scientists have recently proved so fruitful. In order to properly understand Gibbs' propositions, however, he must study the fundamental principles of thermodynamics. These principles, the phase rule and its most important applications, the constitution of saline solutions, of alloys, of solid solutions, etc., are treated, in the book we have before us, with great authority and erudition by Professor P. Duhem, of the University of Bordeaux, the well-known author of several important books."

The publication of this excellent English translation of so valuable a book should be warmly welcomed not only by students of thermodynamics and physical chemistry, but also by students of scientific metallurgy. The English translation contains a general index, which, as usual, was not appended to the French version. The book is brought out with the usual care bestowed by Wiley and Sons on their publications.

The Electric Furnace, by Henri Moissan. Authorized translation by Victor Lenher. 302 6 × 8½-in. pages; 42 illustrations. The Chemical Publishing Co. Easton, Pa. 1904. Price, $3.00, net, postpaid. — This excellent English translation of Professor Henri Moissan's important book will be welcomed by many metallurgists and engineers engaged in various scientific and industrial pursuits. The importance and application of the electric furnace is rapidly gaining ground. Its use has made possible experiments which have added much to our knowledge of many chemical combinations; it has led to the discovery of some hitherto unknown compounds, and for some of these important industrial applications have already been found. With the skillful and fruitful experiments of Moissan our readers are acquainted, and it is a privilege which many will appreciate to be able to read this account from the pen of the master of some of his remarkable work. The book is divided into four chapters, as follows: I, Description of the Different Models of Electric Furnaces; II, Various Modifications of Carbon; III, Preparation of Some Simple Substances in the Electric Furnace; IV, Carbides, Silicides, Borides, Phosphides, Arsenides and Sulphides. It will be seen that the title selected does not do justice to the contents of the book; the "Electric Furnace and its Products" would have been more accurate.

Boiler Construction, by Frank B. Kleinhans. 421 5½ × 7½-in. pages; 334 illustrations; 5 folders. The Derry Collard Co. New York. 1904. Price, $3.00. — This book is written primarily for the shopman, being thoroughly practical and describing the construction of boilers from the laying out of sheets to their completion. Forty ready reference tables are appended to the book. The subject is treated with clearness, system and authority and the book may be highly recommended to boiler constructors. It is well printed and illustrated, but we regret to note that the back is free from any inscription, a serious objection when the book, as is usually the case, is to be kept on a library shelf.

Recherches Physiques et Physico-Chimiques sur l'Acier au Carbon, by Carl Benedicks. 219 6½ × 9½-in. pages; 69 illustrations; paper covers. Upsala. 1904. Price, 10 marks. — This book is a description of the results of an exhaustive study of the properties of some carbon steels undertaken by the author as a thesis for the doctor's degree. The author's name is well known to metallographists, as he has contributed several important papers to the advancement of the science. The present book will be read by them with interest and profit, as it contains much well worth careful attention. The author's contention that he has discovered a new structural constituent in steel containing more than 0.50 per cent carbon will receive special attention. For this new constituent the name of ferronite is suggested. It consists of *Beta* iron holding 0.27 per cent of carbon in solution.

Les Applications des Aciers au Nickel (Applications of Nickel-Steels), by Ch. Ed. Guillaume. 215 6 × 9-in. pages; 25 illustrations; paper covers. Gauthier-Villars. Paris. 1904. Price, 3.50 francs. — The distinguished author of this book, who is associate director of the International Bureau of Weights and Measures, has published a number of important papers, in which he has described the results of his experiments dealing with the properties, and especially the dilatation of nickel-steels. In the book we have before us the contents of these papers have been brought together in a logical and enlarged form. Our readers are familiar with the important industrial applications of some of Mr. Guillaume's results. It will suffice to recall the discovery of " invar," a nickel-steel practically non-expansive, and of " plati-

nite," a nickel-steel having the same coefficient of expansion as glass and which, therefore, may and which is, used instead of platinum in the construction of incandescent lamps. Mr. Guillaume has further shown that by suitable regulation of the nickel-content any desired amount of expansion could be obtained. The theories of nickel-steels are ably presented in an appendix of 20 pages.

Das Roheisen (Pig Iron), by A. Ledebur. 104 6 × 9-in. pages; 20 illustrations; paper covers. Arthur Felix. Leipzig. 1904. Price, 4 marks. — This is the fourth edition of Professor Ledebur's well-known book. It deals with the physical properties of pig iron, the influence of remelting, the testing of cast iron, the selection of suitable grades of pig iron for the production of various castings, etc. It is to be regretted that so good a book has not before this been translated into English.

Ready References Tables; Vol. I, "Conversion Factors of Every Unit of Measure in Use," by Carl Hering. 196 4 × 5-in. pages. John Wiley & Sons. New York. Price $2.50. — These are undoubtedly the most complete and best prepared conversion tables ever published. Their great value to engineers having to deal with various weights and measures need not be insisted upon.

Facts About Peat, by T. H. Leavitt. 115 6½ × 7-in. pages; illustrated. Lee & Shepard. Boston. 1904. Price, $1.00. — In this little book the author claims a great value for peat as fuel and strongly advocates the exploitation of peat bogs. From a perusal of his book we gather that he would have it that peat is as good a fuel as any other used, and, for many purposes, including iron and steel making, even a better one. These opinions, however, the author does not rest upon scientific considerations, or accurate tests, as these are altogether absent from his book, but upon his own experience and the remarks of some others, whose names he seldom mentions. To these extravagant claims, it will suffice to oppose the following remarks, extracted from Prof. A. H. Sexton's book on "Fuel": "Peat is not a good fuel. It contains too much water, very often too much ash — and this usually of an objectionable kind. It contains very little available hydrogen, and has a very low calorific power, about 5,000 B. T. U. or less, and

its calorific intensity is also low. The evaporative power of dry peat may be taken as about 5.5, that of peat in its ordinary condition as 4.5, so that weight for weight its heating power is not more than half that of coal, while bulk for bulk, it is much less. Peat has, therefore, all the defects of wood, with the addition of the high ash, and as it burns it crumbles down, the residue or coke having no cohesive power whatever. The pressed blocks also have this defect, and are usually so soft that they will not bear handling." These we consider to be "*facts about peat,*" as they are not matters of opinion, but the results of scientific and impartial tests. It may be that peat will some day be used extensively, but this can only be after the better kinds of fuel have given out, or their prices have become prohibitive.

Grundzüge der Siderologie; Part III, by Hans Freiherr v. Jüptner. 152 6 × 9-in. pages; 45 illustrations; paper covers. Arthur Felix. Leipzig. 1904. Price, $2.25. — The third volume of this important series is devoted to the relation between iron and various elements. The author's treatment of his subject denotes on his part a masterly knowledge of it. The book is chiefly devoted to a presentation and discussion of the results of the work done during the last twenty years or so by a few students of scientific metallurgy. We miss in this volume the excellent index and bibliography which were appended to the two first volumes. The first volume of the series was translated into English by Charles Salter and it is much to be hoped that the same translater or some other one will undertake the translation of the last two volumes.

PATENTS

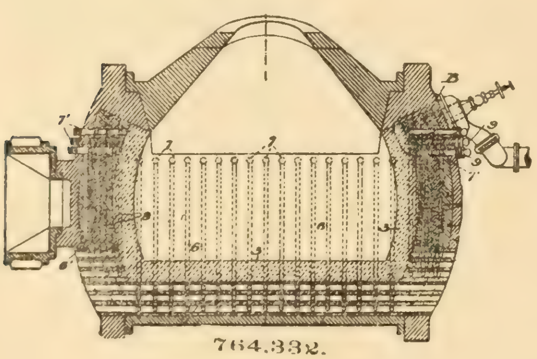
RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

763,460. GAS PRODUCER. — Patrick J. Buckley, Waukesha, Wis. In a gas producer, in combination, a furnace for producing gas and having an air chamber in its walls, a hopper for feeding the furnace and having a cover, a conduit leading from the air chamber to the hopper, and a conduit leading from the hopper to the combustion chamber of the furnace.

763,847. HEATING FURNACE. — Charles W. Bray, Pittsburg, Pa., assignor to American Sheet & Tin Plate Company, Pittsburg, Pa. A metal-heating furnace, comprising a horizontal rotary carrier, an unobstructed heating chamber over said carrier, heating means at one side of said carrier, and arranged to deliver products of combustion on the upper side of said carrier, an outlet for waste products of combustion at the opposite side of said carrier, an air-inlet flue, extending through the walls of the furnace to said heating means, and a stack flue leading from said outlet and arranged adjacent to said air-inlet flue.

763,952. METAL-ROLLING MACHINE. — Peter Blondell, Tonawanda, N. Y. A roll comprising a body portion, a facing sleeve fitting onto said body portion and having apertures formed therein and a groove formed in its inner face, and a die located opposite each aperture, each die having a shank extending through said sleeve and each shank having its inner end headed in said groove.


764,332.

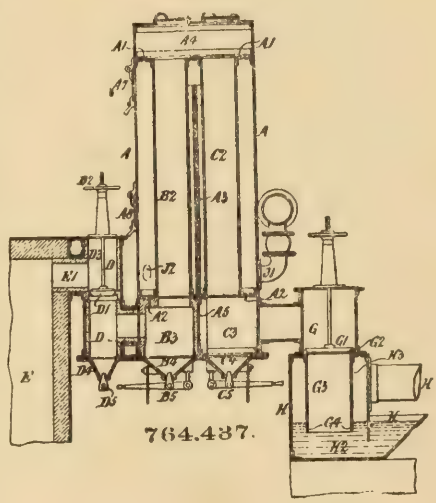
764,174. THERMO-ELECTRIC ELEMENT. — William H. Bristol, Hoboken, N. J. A thermo-electric couple, one element of which consists of tungsten or wolfram steel.

764,332. CONVERTER. — Ralph Baggaley, Pittsburg, Pa. A converter having ventilated passages open to the air at the bottom, and other passages leading therefrom upward along the shell.

763,892. HEATING FURNACE. — Josef Hirschmann, Pittsburg, Pa., assignor to American Tin Plate Company, Orange, N. J. A continuous metal-heating furnace having feed-in and feed-out openings at opposite

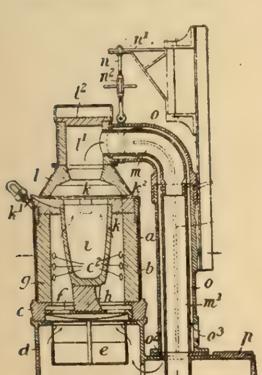
ends and internal supporting ledges, longitudinal water-cooled supporting bars within the furnace and extending beyond the feed-in opening, and external connections arranged to raise and lower the bars and move them endwise, the bars being so arranged relative to the ledges that the outer metal pieces are pushed through the feed-out opening as the bars move endwise in raised position to carry the other metal pieces forward.

764,437. Superheater for Gas Producers. — Alfred B. Duff, Pittsburg, Pa. Superheating apparatus for use in connection with gas producers, comprising, in combination, a circular casing, or shell, a manhole door therefor, upper and lower tube plates therein, an upper box part arranged above the top tube plate and a manhole door in said box, a set of up-comer and of down-comer gas tubes fitted between the tube plates, the area of the tubes and the space between them and the casing being sufficient to admit of cleaning and repairs without dismantling, a baffle or air-deflecting plate fitted between the respective sets of tubes, separated inlet and outlet bottom spaces arranged within the shell below the bottom tube plate and connected respectively to the up-comer and the down-comer sets of tubes, a dust box for each tube fitted to the bottom spaces, an inlet-valved chamber, with dust box attached, connected to the inlet-bottom space and to the main gas outlet of the producer, and an outlet-valved chamber, an inlet and an outlet for air, or air and steam, for combustion in the producer.



764.487.

765,299. Crucible Furnace. Charles W. Speirs, Battersea, London, England, assignor to the Morgan Crucible Company, Ltd., Battersea, London, England. The combination with a casing consisting of two metallic shells, the one being polygonal and the other circular in cross-section, and one being fitted within the other and thereby forming vertical air passages, the inner shell being provided with perforations communicating with said vertical air passages, of a refractory lining within said inner shell having apertures therein adapted to register with those in said inner shell.



765,299.

765,323. Refining Furnace. — Richard Robinson, Pittsburg, Pa., assignor of two-thirds to the Charles E. Brown Company. In a furnace for refining iron and steel, the combination with a melting chamber a series of flues arranged at each end of the melting chamber within the body of the furnace, the central one of said flues being in communication with draft stacks for carrying

out waste gases, and a pair of flues arranged one at either side of the central flue in each of these series of flues adapted to introduce flame to the melting chamber, stand-pipes having controlling valves therein arranged exteriorly and adjacent to the melting chamber, nozzle-forming extensions formed on said pipes and converging toward a common point within the chamber, the said extension being provided with tuyères for introducing a draft into the melting chamber.

765,001. Process of Manufacturing Vanadium and Its Alloys. — Gustave Gin, Paris, France. A process for the electrical manufacture of vanadium alloys which consists in subjecting an anode made of an agglomerated mixture of carbon and vanadium oxide to electrolytic action in a fused bath consisting of calcium fluoride and a fluoride of the metal with which the metal is to be alloyed, introducing the metal with which the vanadium is to be alloyed, in a metallic state in proximity of the cathode, and tapping the resultant alloy product.

765,158. Process of Treating Iron. — James J. Arnold, Covington, Ky. The process of treating iron, which consists in introducing the fresh cool charge into the furnace at a point between the fire and the preceding charge, that the latter acts to heat the fresh charge, and the fresh charge acts to cool the preceding charge by direct absorption of heat.

GREAT BRITAIN

16,853 of 1903. Iron Alloys. — C. Auer von Welsbach, Vienna, Austria. Alloys of iron with metals of the rare earth group, which give off luminous sparks when subjected to abrasion or concussion.

9,314 of 1904. Ball Mill. — W. Grosse, Anhalt, Germany. In ball mills, the provision of means for keeping clear the fine meshes through which the material escapes.

2,273 of 1904. Iron Alloy for Electric Purposes. — R. A. Hadfield, Sheffield. An iron especially useful for electrical purposes, having high permeability and electrical resistance and low hysteresis qualities, made by adding from one to five per cent of silicon to pure Swedish iron.

JOHN AUGUST BRINELL

SEE PAGE 369

The Iron and Steel Magazine

"...... *Je veux au mond publier*
d'une plume de fer sur un papier d'acier."

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NOTES ON CEMENTATION *

By GEORGES CHARPY
Special Contributor to The Iron and Steel Magazine

DURING our investigations of the phenomenon of cementation conducted for several years, we have noted that the perfect regularity of results obtained when cementing superficially some pieces of steel under conditions strictly defined, cannot be produced in experiments whose purpose it is to saturate the metal with carbon at a certain temperature, with a view of ascertaining the solubility of carbon in iron.

From a theoretical point of view, it is very important to ascertain this solubility. Let us bear in mind moreover that the solubility of graphitic carbon in iron must be taken into consideration as well as the solubility of cementite.

The solubility of graphitic carbon may be ascertained with comparative ease, through the analysis of white cast iron which has been subjected to a suitable annealing so as to cause the separation, of the excess of carbon, as graphitic carbon.

* Received November 16, 1903.

Experiments of this kind have been conducted by Forquignon, Royston, etc., and have been frequently quoted on the occasion of the discussion of Mr. Roozeboom's paper on the constitution of the iron-carbon alloys. Since then I have published jointly with Mr. Grenet a series of researches along the same lines. The chief difficulty of this question is due to the extreme slowness of the reaction at relatively low temperatures; because of this slowness, one is never absolutely certain that a state of equilibrium has been reached.

The solubility of cementite is ascertained indirectly through the study of the critical points of steel, as was done notably by Sir Roberts-Austen, whose results served as a base for the construction of Mr. Roozeboom's diagram. It has several times been attempted to obtain some direct information by cementation tests; the only tests of this kind which have been plotted as a curve are those of Mannesmann, which, however, do not give any individual numerical results. The graduation of this curve, which was evidently erroneous, has been corrected by Mr. H. Le Chatelier.

We have again investigated this question and have made numerous experiments with a view of ascertaining the solubility curve of cementite in iron. In the following tables are given the results obtained in subjecting some soft steel wire to the cementing action either of charcoal, of illuminating gas, of cyanide of potassium or of cyanogen.

Effect of Charcoal on Steel Wire Containing 0.04 Per Cent of Carbon

Temperatures Deg. Cent.	Length of Treatment Hours	Carbon Content Per Cent
770	7	0.11
925	2	0.54
950	3½	0.45
960	2½	1.42
1,000	2	0.79
1,000	2	0.47
1,020	2	1.02
1,050	2	1.41
1,050	3	1.79
1,070	2	1.45
1,080	2	0.47
1,125	3	3.12
1,175	wire melted	

Iron Wire (0.04 Per Cent C) Heated in Illuminating Gas

Temperatures Deg. Cent.	Length of Treatment Hours	Carbon Content Per Cent
925	5	0.15
935	6	3.50
935	6	1.76
935	8	1.99
975	8	0.67
1,000	8	1.64
1,025	2	0.24
1,025	6	3.92
1,040	6	2.53
1,050	6	2.53
1,075	5	2.37
1,075	8	1.04

Soft Steel Wire (0.09 Per Cent C) Heated in Cyanogen Gas

Temperatures Deg. Cent.	Length of Treatment Hours	Carbon Content Per Cent
850	½	0.55
880	2	1.79
990	2	4.32

Soft Steel Wire (0.09 Per Cent C) Heated in Cyanide of Potassium

Temperatures Deg. Cent.	Length of Treatment Hours	Carbon Content Per Cent
510	14	0.63
600-700	32	3.77
660	13	0.81
660	7	1.32
745	7	2.60
825	2½	1.25
825	13	1.69
825	14	3.78
837	2½	1.08
875	2	1.10
875	7	1.21
900	13	3.47
945	2	1.19
965	4	1.12
1,035	4	1.54
1,070	2	2.00
1,100	2	2.36

In spite of all the precautions taken the results are very irregular. It may be inferred from the high figures obtained

at the end of long treatments that the limit is never reached. Moreover, the slight differences in the rate of heating, which it was not possible to avoid, in two otherwise identical experiments sufficed to produce notable differences in the amount of carbon absorbed.

In examining some samples under the microscope we noted in some cases the presence of an excess of free cementite and in others, of an excess of graphite. It would seem to follow from these results that it is not possible through cementation experiments to ascertain the solubility of cementite at a high temperature.

We have recently noted that the reasoning by which the separation of the excess of cementite must be explained in experiments of this kind had been presented by Mr. Osmond and by Mr. Sauveur in 1898, in the discussion of a paper by Mr. Saniter entitled "Carbon and Iron" presented to the Iron and Steel Institute.

Mr. Saniter had found that a wire of pure iron heated to 900° C. in charcoal, contained after seven hours 1.64 per cent carbon, after 14 hours 2.79 per cent carbon, after 21 hours 2.95 per cent carbon, of which 0.53 per cent was graphitic. Mr. Saniter then wrote:

"Since in the seven last hours the iron has absorbed only 0.16 per cent of carbon it must be inferred that the saturation point has been reached and corresponds to 2.95 per cent of carbon containing 0.53 per cent of graphite."

Mr. Osmond, discussing these results, wrote in part as follows:

"In practice the limit of carburization at a certain temperature is not easily ascertained experimentally by direct cementation. The temperature must be maintained absolutely constant during the whole of the experiment; if there was even a slight variation of temperature each fall would result in the formation of cementite and the initial deposit could be increased through the variations of the temperature.

"This frequently occurs in the crystallization of salts. The cementite thus isolated during the cementation must be substracted from the total cementite found after cooling. The dissociation of carbide of iron and the possible formation of graphite increase still more the complexity of the phenomenon."

We quote this portion of Mr. Osmond's discussion because we were recently led to express the same opinion almost in the same words, without knowing that Mr. Osmond had expressed it several years before.

It seemed desirable to conduct a few additional experiments in order to verify the accuracy of this reasoning, by exaggerating certain conditions. We were thus able to ascertain that through a sufficiently long treatment, it was possible to convert some iron wholly into a carbide of iron. This result can only be obtained at a relatively low temperature for it is necessary to prevent the decomposition of the iron carbide resulting in the production of graphite. On the other hand, at a low temperature, the diffusion of carbon in iron is very slow; it is, therefore, necessary to use some very small pieces of iron, widely different results being obtained according to the size of the fragments of iron used.

The following experiment will illustrate the results obtained:

Some fine filings of soft steel containing 0.09 per cent carbon were heated to a temperature of about 650° in melted cyanide of potassium. After various lengths of time a small portion of the filings was tested for carbon, with the following results:

After 48 hours	4.50 per cent carbon
After 85 hours	6.72 per cent carbon
After 110 hours	6.72 per cent carbon

The formula Fe_3C representing the iron carbide calls for 6.67 per cent carbon. After 86 hours, therefore, the iron was wholly converted into cementite and a longer treatment did not cause any further absorption of carbon. The resulting product was undoubtedly cementite; it dissolved completely in acids and did not contain any trace of graphitic carbon.

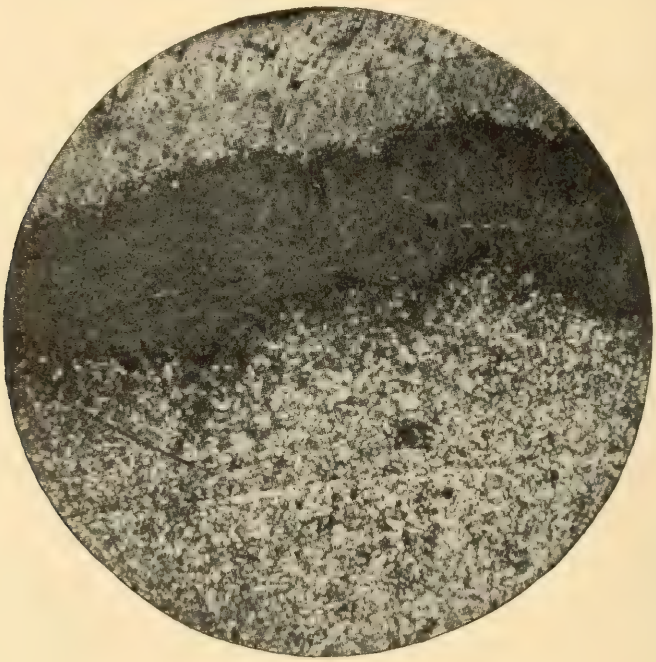
When a fragment of steel of a certain dimension is treated under the same conditions, it is observed that a layer of nearly pure carbide is formed on the outside, and this layer cracks when the metal is bent and may be detached in the shape of small chips.

In examining under the microscope a section of a steel bar subjected to a prolonged cementation at a low temperature, under this layer of cementite, a layer of metal containing a decreasing amount of carbon is clearly seen.

The accompanying photo-micrograph illustrates this appearance.

When the experiment is conducted at a higher temperature, the carbide of iron, which is not a stable compound, is decomposed with the production of graphite.

I have shown jointly with Mr. Grenet in our paper on "Equilibrium of Iron-Carbon Alloys" that this decomposition begins in an irregular manner, but once started it proceeds with varying speed, even at low temperatures. As soon as a little graphitic carbon has been formed, the carbon which is dissolved at one point is separated at another as graphite, and as the separated product contains no iron, the reactions may continue



indefinitely, through a mechanism similar to that which has been explained in the case of the separation of the excess of cementite. The following experiments will illustrate our reasoning:

A piece of soft steel containing 0.09 per cent carbon and measuring three mm. in diameter was maintained during 64 hours at 1,000° C. in illuminating gas. It contained 8.32 per cent of total carbon and 7.66 per cent graphitic carbon.

Some steel filings containing two per cent of carbon were heated in pure carbonic oxide. One sample heated for two hours to 900° contained 3.27 per cent carbon, another sample

heated to 900° for four hours contained 4.90 per cent carbon; a third sample heated to 1,000° for one and one-half hours contained 2.66 per cent carbon; finally a sample heated to 1,000° for 36 hours contained 9.27 per cent total carbon, and 8.27 per cent graphitic carbon.

It seems evident that the cementation of a piece of steel, at a certain temperature, is not limited by the solubility of cementite at that temperature, and may after a sufficiently long time, give rise, in the interior of the steel, to the formation either of crystals of free cementite, or of particles of graphite.

This segregation, however, takes place only in the vicinity of the saturation point and does not, therefore, occur in practice. In practical operations, it will be important to remember that, since cementation is not automatically limited, it will be necessary, in order to secure uniform results, to conduct the operation always under exactly the same conditions. In heating some pieces of steel of identical dimensions in the same carburizing material, during the same time and at the same temperature, the same degree of cementation will always be obtained. The extent of cementation may be varied by suitable variations of one of the factors just mentioned, and this possibility of empiric regulation will suffice in practice.

What we have just said regarding cementation is not, however, of universal application for some conditions may be conceived under which the cementation is automatically limited. This might be the case, for instance, when using some carburizing material, whose decomposition results in a product having a tendency to decarburize the metal, and this happens when using gaseous substances such as carbonic oxide, cyanogen and hydrocarbons.

Carbonic oxide carburizes iron in a marked manner. This result was questioned by Percy, Caron, Ledebur, etc., but was proved by Marguerite and we have confirmed it by numerous experiments. Our tests consisted in heating some steel in a slow current of carefully purified carbonic oxide. The gas was prepared by means of ferro-cyanide and sulphuric acid and absorbed in a solution of cuprous chloride in hydrochloric acid. Before being passed over the metal it was purified by means of silver nitrate, lime and sulphuric acid.

In each experiment the increase in weight of the metal was

ascertained as well as the quantity of carbonic acid evolved. The metal was then heated in a current of oxygen in order to ascertain the amount of carbon absorbed. This carbon was either free or dissolved in the metal. To distinguish between these two varieties, the metal used was in the shape of wires which could be cleaned from all pulverulent deposits before weighing and burning.

It was found in this way that above 750° there was practically no deposit of pulverulent carbon due to the dissociation of carbonic oxide; the metal remains perfectly clean and brilliant, but is decidedly carburized. In most experiments similar results were obtained in determining the amount of carburization either by increase of weight of the metal, by combustion or by the amount of carbonic acid produced.

At low temperatures both a deposit of pulverulent carbon and cementation take place. We succeeded in cementing steel at 560° C.

The following table contains some of the results obtained:

Temperatures Deg. Cent.	Length of Heating Hours	Carbon Absorbed by the Metal		
		From Increase in Weight of Metal Per Cent	From Combustion of the Metal Per Cent	From the Weight of CO_2 Formed
560	8	0.10	0.09	Deposit of Carbon
600	8	0.22	0.17	Deposit of Carbon
715	8	0.26	0.28	Deposit of Carbon
825	3	0.56	0.57	0.60 Per Cent
925	2	0.69	0.72	Tube Broken
935	2	0.41	0.41	0.49 Per Cent
1,025	2½	0.60	0.58	0.58 Per Cent
1,050	2	0.44	0.47	0.44 Per Cent
1,085	2	0.53	0.53	0.58 Per Cent
1,125	2	0.46	0.50	0.47 Per Cent
1,175	2	0.47	0.47	0.51 Per Cent
1,185	2	0.53	0.53	0.47 Per Cent
1,190	2	0.30	0.36	0.33 Per Cent

It is seen that the speed of cementation does not notably increase at temperatures exceeding 900°; saturation, however, is not reached since by increasing the time of contact between the iron and carbonic oxide the separation of graphitic carbon takes place, as mentioned above.

Carbonic oxide carburizes the steel and carbonic acid is formed; this gas may now decarburize the steel which has just

been carburized. It follows from this that if steel be heated in contact with a limited amount of carbonic oxide, carburization will cease after a certain amount of carbonic acid has been formed. This will also occur with cyanogen which in carburizing iron gives rise to the formation of carbon and nitrogen, and also with hydrocarbons whose decomposition results in the formation of carbon and hydrogen, since both nitrogen and hydrogen have a powerfully decarburizing influence, as mentioned by Forquignon and ascertained again by us. Some steel filings containing three per cent carbon, when heated to 1,000° C. either in nitrogen or in hydrogen, were completely decarburized in both cases after four hours.

It follows from these considerations that cementation could be carried on so that the amount of carbon absorbed will be regulated automatically, by using as cementing substance, a continuous current of a gaseous mixture containing definite proportions either of carbonic oxide and carbonic acid, of cyanogen and nitrogen, or of hydro-carbon and hydrogen.

We must also mention a peculiarity of the cementation by carbonic oxide. This cementation, which takes place very readily with iron, does not occur with such metals as manganese and chromium. The last-named metal especially, when subjected to the action of carbonic oxide, absorbs the oxygen of that gas and is converted into a mixture of sesquioxide of chromium and of carbon. Chromium retains this property when alloyed with other metals, and this is of importance, since chromium steels are being used more extensively. When some chromium steel is subjected to the action of a current of carbonic oxide, some cementation takes place, but at the same time also some oxidation, which, however, appears to be confined to the chromium, and occurs only on the outside, because the oxide of chromium produced does not diffuse through the metal. The result may also be produced in cementing with solid substances because many of them give rise to the formation of carbonic oxide, and it has seemed to us important to mention it because it might lead to wrong conclusions in dealing with chromium steels.

SOME PHENOMENA IN THE SHRINKAGE OF CAST IRON*

By THOS. D. WEST

Written for The Iron and Steel Magazine

WE have in the making of all castings the evils of shrinkage and contractions to contend with. The former being an action reducing the bulk of metal in cooling down from a liquid to a solid state, while the latter implies a reduction in size after the metal has solidified in cooling down to the temperature of the atmosphere. In making castings from iron that has been remelted in a cupola or air furnace, the softer the iron the less shrinkage found, but why the reverse should occur in making castings with liquid metal direct from the blast-furnaces is a phenomenon which bears investigation. In the late use of "direct metal" in Bessemer irons for making ingot mold and other castings, the writer has been surprised to find the great shrinkage that occurs in soft irons or those having over 1.25 in silicon compared to metal under 1.25. It is well known by blast-furnace men that when direct Bessemer metal exceeds 1.25 in silicon and is below 0.03 in sulphur there is considerable escape of carbon in the form of graphite or commonly called "kish," especially with iron low in manganese, as this element assists iron to absorb or hold carbon. This is generally so excessive with metal above 1.30 in silicon and low in sulphur and manganese that the ground will often be covered for many feet around a ladle or a pig bed with flakes of graphite, and be so mushy as to be very bad for pouring castings. Take this same metal after being poured in pigs or castings and remelt it, and all evidence of existing freed carbon or kish coming from the liquid metal is lost. This would demonstrate that the metal after being evolved

* Received September 9, 1904.

from its ores had ejected what carbon could not be held in the iron and also the great influence of silicon to repel or prevent iron absorbing carbon. Why we do not observe kish in remelted iron is due to two factors, the first being that the excess of carbon had been nearly or all ejected from the iron when coming from the blast-furnace and then if any excess did remain it was assisted to be retained by the fact that remelting iron reduces silicon and increases sulphur, two things which permit iron to retain more carbon than if these conditions were reversed. This clears the question of liberation of graphite to make kish, but when we return to explain the cause for the excessive shrinkage, noted above, all does not appear such an open book, as after direct metal is poured into a casting the expulsion of freed carbon, as far as evidence exists, ceases.

There appears to be a certain temperature, or that about midway between the hottest or most fluid state and the point of solidification, at which the greatest ejection of graphite takes place. High graphitic metal gives one the impression of its being affected by something that makes the metal mushy and expands its bulk. The fact that it shrinks so much before solidifying sustains the last supposition; and, as we now know, as was discovered by the writer along in 1896, that soft iron has less expansion at the moment of solidification than hard iron, it is another evidence to sustain the belief that soft direct metal is expanded while in a fluid state through the influence of freed carbon more than is the case with harder irons, and hence, being in a higher expanded state when fluid, greater shrinkage occurs at or near the moment of solidification, thus explaining the cause of the phenomena of which this article is the main subject.

Another interesting factor which the ejection of graphite would point to is to raise the question, if it is true that all carbon finally held in liquid iron, or after the ejection of graphite ceases, is held in the metal before it solidifies as combined carbon or in a chemical form, instead of being mechanically mixed as is the case with graphite. We know it is claimed that any carbon existing in liquid iron is all held in the combined form, but the fact as shown herein that some carbon is ejected as graphite would lead to a modification of the above claims for direct metal, as we lack evidence to prove whether all the graphite is expelled before the direct metal nears its point of solidification.

Another factor to be kept in mind in connection with a study of this shrinkage question is the fact that, when direct Bessemer metal gets below 0.50 in silicon and above 0.03 in sulphur, to make "white iron" in bodies under three-quarters of an inch thick, we again have an excess of shrinkage to contend with, but which is not as great as when the metal is above 1.25 in silicon and below 0.03 in sulphur, and then again while we have considerable shrinkage with direct metal in hard grades there is not near that found which occurs with remelted hard irons of similar analysis.

The point of least shrinkage in direct metal generally occurs in irons having from 0.75 to 1.00 in silicon and 0.01 to 0.02 in sulphur. A peculiar coincidence in this line lies in the fact that there appears to be a normal point to generate the least shrinkage, similar as in obtaining the strength of cast iron and which, as is well known, increases in attaining hardness up to a certain point, and after this is reached then the strength decreases.

In referring to the physical properties it is to be said that direct metal, of right grade, has proven superior to cupola or remelted iron for durability in casting, subjected to heat expansion and contraction strains. In fact all direct metal of right grade should prove better for such work in comparison to remelted iron of similar analysis, especially where the evils of any kish can be contrôlled in making castings for the reason that in its initial or first melted cooled state a greater elasticity should exist than in remelted iron.

While it is to be said that this article presents original matter it also sets forth with its facts ideas for valuable research and will cause many to have something new to think about.

A RADICALLY NEW METHOD FOR THE DETERMINATION OF SULPHUR IN IRONS AND STEELS*

By H. B. PULSIFER

Written for The Iron and Steel Magazine

IT is with some hesitation one proposes a new method for a determination so long and ably carried on as the determination of sulphur in irons and steels. However, it must be admitted, that the two methods at present recognized as giving accurate results, namely, the nitric acid method and Bambers' method, are by no means ideal.

These methods are too well known to require description here; Ford and Willey have ably criticized them in a recent article in the "Journal of the American Chemical Society." The author heartily shares their opinion that, for accurate results with the nitric acid method, great care is necessary.

Although these methods may be accurate when solution takes place slowly, because of this necessary slowness, they lose their commercial value. An ideal method is one which should not lose accuracy when conducted by a skillful but rapid manipulator. Hastening the solution of the iron when dissolved in nitric acid does give low results while if one resorts to evaporation on a hot plate there is much danger of losing sulphur by bumpings. To devote three-quarters of an hour to the solution, alone, makes this a very tedious method indeed.

In view of these facts the author devised and tried the method which will be found below. The time between weighing the sample and precipitating the barium sulphate need not be more than twenty minutes.

Outlined, the process is as follows: The sample is dissolved in chloric, hydrofluoric, and hydrochloric acids; the residue is then filtered, fused with sodium peroxide, and the fusion dissolved in water and hydrochloric acid. Meanwhile the hydrofluoric acid from the first filtrate has been boiled off and the two portions are now united and the sulphur precipitated as barium sulphate.

Every step, excepting the boiling off of the hydrofluoric acid, is susceptible of quick and easy manipulation. The solution re-

* Received September 9, 1904.

quires not over two minutes, the silica-free residue filters very rapidly with suction, while the fusion and its dissolving takes less than five minutes. As a matter of fact several of the results given below took just under twenty minutes between weighing and precipitating.

Hendrixon* has shown that iron is quickly and completely dissolved by chloric acid, and that every trace goes to the ferric condition. This also oxidizes the sulphur as the results show. The residue, however, retains some of the sulphur and its separation from the solution by suction filtration without removing the silica is an endless task, hence the use of hydrofluoric acid. A shorter method for this step would be highly desirable, but even as it is it is not too tedious and it unquestionably greatly assists in the rapid solution of the iron, its freeing the iron from silica giving the chloric acid full play on the iron.

The fusion of the residue with sodium peroxide is a very neat and easily performed operation. Once while putting the sodium peroxide into the crucible on top of the folded moist filter containing the residue, the crucible having just been removed from the flame where it had been drying, sufficient heat remained to ignite the mass, and the whole fusion was completed in five seconds. It is also a pleasure to dissolve and filter a peroxide fusion, as it does not require that patience-trying deliberation needed for the solution and filtration of a sodium carbonate fusion.

The exact details by which the following results were obtained will now be given:

Two and five-tenths grams of the sample are placed in a 250 cu. cm. broad Jena beaker and just fairly moistened with water. The particles inevitably tend to fuse together if chloric acid is put directly on the iron and the mass is then difficult to get into solution.

Twenty cu. cm. chloric acid, 1.12 sp. gr., are added and a very little hydrofluoric acid. In 15 seconds the bubbles are at the top of the beaker but have never been known to go over. In 45 seconds the action has subsided and five cu. cm. of strong hydrochloric acid may be added, the beaker covered with a watch glass and any particles on the sides brought down by boiling.

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* "Journal of the American Chemical Society," 26, 747.

It might appear feasible to boil off the excess of hydrofluoric acid at this point, but it was found that this always gave low results.

The filtration is now made by suction using a seven-cm. filter. The filter is washed two or three times with as little water as possible and then sucked as dry as may be.

To the filtrate 20 cu. cm. of strong hydrochloric acid are added and the whole boiled down over a naked flame, with constant shaking until the volume is under 10 cu. cm. and the mass begins to get oily; it is then placed on one side until the portion from the residue is ready to add.

Meanwhile the residue has been placed in a 20 cu. cm. nickel crucible and covered with sodium peroxide, the cover is then held down by the tongs while a strong flame heats the crucible. The action begins with a little pop and in a few seconds it is over; as soon as the fusion is solid it is cautiously placed in a beaker containing 50 cu. cm. of water. Hydrochloric acid is added, and in some two minutes all has dissolved, and the few shreds of unburned carbon may be filtered off while the filtrate goes into the main portion already prepared and waiting.

The whole volume is now about 100 cu. cm. and is ready for the barium chloride solution.

The sulphur was determined separately in the two portions in the following analyses so that the amount in the residue might be known.

Treadwell says that the presence of ammonium salts prevents the precipitation of barium fluoride, but this is very questionable indeed, and not confirmed by the author's experiments.

Of course all the reagents used were tested for sulphuric acid. In portions as large as used for an analysis none of them gave even a turbidity, with barium chloride. Blanks were also carried through to prove that the hydrofluoric acid had been all removed by boiling as described.

No. 1. — A No. 1 Foundry Iron, Si = 2.97 per cent:

Sulphur by usual rapid method..........	0.008 per cent
Sulphur by very slow solution...........	0.013 per cent
Sulphur by new method:	
Filtrate	0.012 per cent
Residue	0.006 per cent
Total	0.018 per cent

No. 2. — A No. 2 Foundry Iron, Si = 2.00 per cent:

Sulphur by usual rapid method		0.004 per cent
Sulphur by very slow solution		0.003 per cent
Sulphur by new method:		
Filtrate	0.022 per cent	
Residue	0.000 per cent	
Total	0.022 per cent	

No. 3. — A Steel, Total Carbon = 1.18 per cent:

Sulphur by usual rapid method		0.017 per cent
Sulphur by very slow solution		0.023 per cent
Sulphur by new method:		
Filtrate	0.016 per cent	
Residue	0.011 per cent	
Total	0.027 per cent	

No. 4. — A No. 1 Foundry Iron, Si = 2.84 per cent:

Sulphur by usual rapid method		0.017 per cent
Sulphur by very slow solution		0.019 per cent
Sulphur by new method:		
Filtrate	0.026 per cent	
Residue	0.020 per cent	
Total	0.046 per cent	

No. 5. — Also a No. 1 Foundry Iron, Si = 2.80 per cent:

Sulphur by usual rapid method		0.048 per cent
Sulphur by very slow solution		0.065 per cent
Sulphur by new method:		
Filtrate	0.054 per cent	
Residue	0.008 per cent	
Total	0.062 per cent	

No. 6. — A Very Soft Cast Iron, Si = 2.60 per cent:

Sulphur by usual rapid method		0.080 per cent
Sulphur by very slow solution		0.091 per cent
Sulphur by new method:		
Filtrate	0.076 per cent	
Residue	0.022 per cent	
Total	0.098 per cent	

No. 7. — A Very Hard Cast Iron, Si = 2.70 per cent:

Sulphur by usual rapid method..........	0.148 per cent
Sulphur by very slow solution...........	0.164 per cent
Sulphur by new method:	
Filtrate	0.134 per cent
Residue	0.021 per cent
Total	0.155 per cent

The rapid method referred to is the standard method of solution in strong nitric acid and addition of strong hydrochloric acid when the first action of the nitric acid has ceased. It takes twenty minutes and gives low results.

The very slow method referred to is the same method exactly, except that the solution is made so slowly that at no time do nitric fumes come off rapidly. Solution takes at least thirty minutes, evaporations fifteen more.

Sample No. 3 was a steel in two small pieces and by all methods took much more time than the samples in the form of drillings.

At the present time chloric acid is a rather expensive chemical for commercial work; however, it will probably be sufficiently cheap if there be much demand for it. Even at its present price it is not too dear, and if the accuracy of the method be sustained it may become the most desirable method after all. The acid with sp. gr. 1.12 is the only one readily obtainable; stronger acids might so reduce the amount of sulphur left in the residue that a fusion would not be necessary, which would greatly add to the desirability of the method.

The method is proposed for routine analysis in all sorts of laboratories, and if it does not come into general use it can at least serve as an independent check method for other methods.

Laboratory of the Henry Souther Engineering Co., Hartford, Conn., August 19, 1904.

ELECTROMETALLURGY OF IRON AND STEEL*

IN the metallurgy of iron and steel the use of the electric furnace has so far been mainly successful on a commercial scale for the solution of two special problems. The one is the manufacture of ferro-alloys, the other the production of special steels. For the production of ferro-alloys it is the ease of producing very high temperatures by means of the electric furnace which has made its application preferable and in some cases necessary on account of the high temperature of reduction of the oxides (of titanium, etc.) to be reduced. On the other hand, the features which render the electric furnace very suitable for the manufacture of special steels, are the ease of control, the cleanliness of operation, and the absolute prevention of impurities being introduced into the charge from furnace gases. However, these are not the only problems in which electrochemists have tried to introduce the electric furnace in the iron and steel industry. The big problem — that of the reduction of iron ores and the manufacture of iron and steel from the ores — has repeatedly been attacked, although no process of this kind has so far been able to prove its practicability on a large commercial scale.

A great amount of such pioneer work has been done in Europe. The reason is a peculiar one which has really nothing to do with iron and steel. When some years ago it was found that calcium carbide could be easily made in the electric furnace and that by means of the simple reaction of the calcium carbide with water, it was possible to get acetylene, promising to be of great importance for the lighting industry, there was started a great boom, and wherever there was a water-power a calcium carbide plant was erected in Europe. It must be understood that the calcium carbide industry in Europe is not in the hands of a single company, as it is in this country. The result was overproduction, a collapse of prices and a serious crisis in the calcium carbide industry of Europe. The question was now what to do with electric-furnace plants which had been erected, and in this crisis nothing seems to have attracted the attention of the European electrometallurgical engineers to a greater degree than the

* "Electrochemical Industry," July, 1904.

possibilities of electric-furnace processes in the iron and steel industries. In former issues we have described in detail nearly all the more important attempts which have been made in this direction.

The matter has become of great actual importance in this country on account of the interest which the Canadian Government has taken in this matter, with a view of introducing an electric iron and steel process on a large scale in Canada, where large water-powers and cheap iron ores are available. A commission appointed by the Canadian Government, and headed by Dr. Eugene Haanel, was sent to Europe to investigate the different electric-furnace processes in question, and the committee has recently returned, convinced that its trip had been entirely successful.

A summary of the main facts ascertained by the committee and embodied in its report to the Canadian Government has recently been given in the "Canadian Manufacturer," from which we take the following passages:

Keller Furnace. — By far the most important experiments witnessed by the commission were those made by Mr. Keller, of Keller, Leleux & Co., in Livet, France. Some 90 tons of iron ore were used to show the economic production of pig iron by the electric process. The furnaces employed for these experiments were the furnaces used in the regular work of the company for making the various ferro-alloys, such as ferro-silicon, ferro-chrome, etc. The company at the time of the visit of the commission were under contract to furnish ferro-silicon to the Russian Government, but generously interrupted their pressing regular work to undertake the making of experiments for the commission. The furnace employed is of the resistance type, and consists of two iron castings of square cross-section, forming two shafts communicating with each other at their lower end by means of a lateral canal. The cases are lined with refractory material. The base of each shaft is formed by a carbon block. These blocks are in electric communication on the exterior of the furnace by means of copper bars. The carbon electrodes to which electric current is distributed pass two-thirds of their length into the shaft. The electrodes are prisms 72 cm. (28 inches) in diameter and 135 cm. (53 inches) long. Three sets of experiments were made, as follows: 1. Electric reduction of iron ore and obtaining different

classes of pig, gray, white and mottled. 2. Electric reduction of iron ore containing a definite amount of carbon in the charge, with a view of ascertaining the amount of electric energy absorbed in the production of one ton of pig iron. 3. The manufacture of ordinary steel of good quality from the pig manufactured in the preceding experiments.

The different classes of pig iron were obtained without difficulty, and the furnaces throughout the experiments worked quietly and without the slightest accident, the gas discharging on top in flickering flames, showing that the gas resulting from the reduction of the ore escaped at low pressure. The workmen employed were ordinary Italian laborers without any special training. A number of castings, such as columns, pulleys, gear wheels, plates, etc., were made, the metal drawn directly from the furnace. The castings showed sharp edges, a comparatively smooth surface, and were sound throughout.

For the determination of the electric energy absorbed, the voltmeter and ammeter employed to measure the volts and amperes were calibrated in the laboratory of the director of the electrical department of the University of Grenoble, who also ascertained the power factor of the alternator furnishing the electric energy. The electric energy absorbed per ton of pig was found to be 0.226 horse-power year.

Cost of Process

1.	Ore (hematite metallic iron 55 per cent), 1.842 tons at $1.50 per ton	$2.76
2.	Coke for reduction, 0.33 tons at $7 per ton	2.31
3.	Consumption of electrodes at $5 per 220 pounds	0.77
4.	Lime	0.30
5.	Electric energy, 0.226 horse-power year at $10 per each horse-power year	2.26
6.	Labor at $1.50 per day	0.90
7.	Different materials	0.20
8.	General expenses	0.40
9.	Repairs, maintenance, etc	0.20
10.	Amortization (machinery and buildings)	0.50
	Total, exclusive of royalty	$10.60

To satisfy the commission, Mr. Keller made experiments to illustrate his process of making steel. The details of the operation

and the figures relating to his experiments are in the hands of Professor Harbord, the English metallurgist, who accompanied the commission.

In regard to other processes it was found that Mr. Harmet of St. Etienne, who published papers and obtained patents on the electric process for smelting iron and making steel and Mr. Gin of Paris, who has obtained a patent for the production of steel from scrap, have as yet no plant in operation by which their methods might be tested.

Prospects of the Electric Furnace. — In his general conclusion, Dr. Haanel says: "It must be pointed out that the results obtained at Livet were the results of experiments in furnaces not specially adapted to the work required to be done. With the improved furnaces of which the commission has secured detailed drawings, permitting on account of higher column of charge a more effective use of the reducing power of the carbon monoxide evolved, and the employment of machinery for charging the furnace to reduce the cost of labor, a much better figure than the one given will result."

The processes of electric smelting must yet be regarded as in the experimental stage, no plant existing at present where iron ore is commercially reduced to pig by the electric process. The more remarkable therefore it appears that experiments made off hand, so to say, in furnaces not at all designed to be used for the production of pig, should give a figure of cost which would enable an electric plant properly designed and managed to compete with the blast-furnace. It is, moreover, reasonable to expect that, as experience in electric smelting accumulates, the design of the electric furnace best suited to the conditions of the high temperatures with which the metallurgist has to deal will undergo changes which will reduce the absorption of electric energy to a minimum. The electric engineer will also be called upon by the new industry to design electric plants specially suited to the conditions of electric smelting.

When it is considered that the electric process is applicable to the smelting of all other ores, such as copper, nickel, silver, etc., that the furnaces are of simple construction and the regulation of the heat supply is under perfect control, we may expect that the application of electric energy to the extraction of metals from their ores will not be long delayed, and that familiarity with

handling large currents, and experience gained in electric smelting will result in displacing some of the costly and complicated methods by comparatively simple and economic processes. The immediate effect of a plant erected for the smelting of iron ores which will demonstrate the economic production of pig and the making of steel will arouse the faith of the industrial world in the new metallurgy, and other industries, dependent upon electricity as the agent or to which electricity can be applied will follow as a consequence in the wake of this power plant.

Manufacture of Special Steels. — At Gysinge, Sweden, steel of superior quality is made by the smelting together of charcoal, pig and scrap in an electric furnace of the induction type — that is to say, a furnace without electrodes. This process corresponds to the crucible steel process, but it has certain advantages over the latter in that the melted materials at no time during the operation are exposed to gases, some of which when absorbed deleteriously affect the quality of the product. The furnace worked quietly and regularly, producing on the average four tons of steel in 24 hours. Tapping occurring every six hours, 0.116 electric horse-power years were required per ton of product. The cost at the rate of $10 per electric horse-power a year would be $1.16 per ton of product. At Kortfors, Sweden, the Heroult process of making steel is in operation, but the furnace is at present employed in the making of ferro-silicon.

At Lapras, France, steel is also made from melted scrap. The process differs from that at Gysinge, in that it permits of the purification of the materials employed, two slags being made for that purpose, and carburization is effected in the furnace by carbon briquettes. The furnace is of the tilting pattern, consisting of an iron casing lined with dolomite brick. The bottom of the furnace is filled on top of the lining with crushed dolomite, upon which the charge reposes. Two electrodes pass through water-cooled joints in the roof of the furnace. The electrodes are vertical and parallel, and are adjusted vertically either by hand or a specially constructed regulator. An alternating current of 4,000 amperes of 110 volts is distributed to the electrodes. Different classes of steel are made by the company at a cost per electric energy absorbed of $1.54 per ton of ingot. The selling price of the steel varies from 363 francs 60 centimes to 123 francs 60 centimes per ton, depending upon quality.

Interesting experiments were made for the commission at this plant in the production of pig from the ore in a very simple furnace consisting of an iron box of rectangular cross section, open on top and lined with refractory material. The bottom of the furnace in communication with the iron casing constituted one terminal of the electric circuit. A carbon electrode of square cross-section and about three feet in length, placed vertically in the open top of the furnace, constituted the other terminal. By hand regulation this electrode could be lowered or raised within the furnace. Thirty charges of ore were made during the working, and thirteen taps of metal and slag were taken.

THE IRON AND STEEL WORKS IN THE UNITED STATES

THE sixteenth edition of the "Directory to the Iron and Steel Works of the United States," compiled and published by the American Iron and Steel Association, has just been issued. It is reviewed elsewhere in this issue. The preface to this edition is so full of extremely interesting data that we reproduce it slightly abridged in the following pages:

The opinion has been frequently expressed that the organization in the iron trade in recent years of many so-called "trusts," particularly of the United States Steel Corporation, would result in a serious check to individual enterprise or to the enlistment of comparatively small firms and companies in the manufacture of iron and steel. An examination of the present edition of the Directory will show that apparently precisely the opposite effect has been produced, or at least that the "trusts" have not interfered with the growth of our iron and steel industries under independent auspices. A surprisingly large number of independent iron and steel plants have been built in the last few years, while many old and well-established companies have greatly increased their facilities in these years for the manufacture of iron and steel. Especially has there been a marked

development of independent enterprise in the manufacture of iron and steel specialties, of which steel castings may be mentioned as a leading example.

Whole Number of Blast-Furnaces. — In the edition of the "Directory" for 1901 we described 406 completed furnaces as being then active or as having been reported to us as likely to be some day active. We gave the annual capacity of these furnaces as amounting in round numbers to 24,800,000 gross tons, not all of which capacity could, of course, be employed at the same time nor would some of the furnaces enumerated ever run again. In the present edition we describe 428 completed furnaces, either active or reported to us as likely to be some day active. Eliminating some of the furnaces in the latter category as being in our opinion dead for all time there remain about 410 live furnaces to-day. The annual capacity of these furnaces we place in round numbers at 27,675,000 gross tons. Our actual production of pig iron in 1903 was 18,009,252 gross tons. Since 1901 we have transferred 21 furnaces to the abandoned, dismantled, or inactive list.

Furnace Building. — When the Directory for 1901 appeared 12 furnaces were being built, namely, two in New York, one in New Jersey, three in Pennsylvania, one in West Virginia, two in Alabama, one in Michigan, and two in Colorado. In the present edition we enumerate 17 furnaces in course of erection or as being rebuilt, namely, three in New York, five in Pennsylvania, one in Virginia, two in Alabama, four in Ohio, one in Michigan, and one in Colorado. In the figures for both years we do not include projected furnaces or furnaces that had been undertaken and work upon which had been suspended.

Fuel Used in Blast-Furnaces. — The 406 furnaces described in the edition for 1901 were classified as follows; 55 used charcoal as fuel, five used mixed charcoal and coke, and 346 used anthracite and bituminous fuel. Of the 428 furnaces that are now described 56 use charcoal and 372 use anthracite and bituminous fuel. No furnaces now use mixed charcoal and coke. Five furnaces, not included above, make ferro-silicon, ferro-chrome, ferro-tungsten, etc., by electricity.

Capacity of Furnaces According to Fuel Used. — The average annual capacity of the 55 charcoal and five mixed charcoal and coke furnaces in 1901 was 14,179 gross tons, and the average

annual capacity of the 56 charcoal furnaces that are now described is 15,207 tons. The average annual capacity of the mineral fuel furnaces in 1901 was 69,252 tons; in June, 1904, it is 73,286 tons.

Rolling Mills and Steel Works. — In the edition of the "Directory" for 1901, we enumerated 527 completed rolling mills and steel works, 28 in course of erection, one being rebuilt, one to be rebuilt, and six projected. In the present edition we enumerate 572 completed rolling mills and steelworks, 12 in course of erection, one being rebuilt, and two partly erected. In addition the "Directory" mentions 14 projected plants. The annual capacity of the completed rolling mills in 1904, amounts to 25,978,050 tons of finished rolling products as compared with 23,220,350 tons in 1901.

Puddling Furnaces. — The number of puddling furnaces in November, 1901, each double furnace counting as two single furnaces, was 3,251. In June, 1904, there were 3,161 puddling furnaces. The highest number of puddling furnaces reported in any edition of the "Directory" was in 1884, when 5,265 were enumerated.

Bessemer Steel Works. — The total number of completed Bessemer steel works in November, 1901, including one Clapp-Griffiths plant, two Robert-Bessemer plants, and nine Tropenas and "special" Bessemer plants, was 47, and the whole number of converters was 100. In June, 1904, there were 32 standard Bessemer steel works with 75 converters, one Clapp-Griffiths plant with one converter, two Robert-Bessemer plants with three converters, ten Tropenas plants with 14 converters, one Bookwalter plant with one converter, one Evans-Wills plant with two converters, and four plants with seven converters which make steel by special processes; total number of Bessemer plants, 51; total number of converters, 103. The increase in the number of small Bessemer plants in the last few years is noteworthy. Since November, 1901, six standard Bessemer plants with 15 converters have been dismantled. In addition two Tropenas plants with three converters have been abandoned. The annual capacity of the completed and building Bessemer converters in November, 1901, was 12,998,700 gross tons. In June, 1904, it was 13,628,600 an increase of 629,900 tons. No Basic-Bessemer steel is made.

Open-Hearth Steel Works. — The "Directory" for 1901

described 112 completed open-hearth steel plants, with 403 completed furnaces. In the present "Directory" we describe 135 completed plants, with 549 completed furnaces. In 1901, 12 open-hearth plants with 40 furnaces were building, one plant was to be rebuilt, 13 plants were projected, and six furnaces were being added to existing plants. In June, 1904, five open-hearth plants with nine furnaces were building, two plants with three furnaces were partly erected, 17 plants were projected, and 13 furnaces were being added to existing plants. In addition one open-hearth steel plant which has four completed furnaces had three furnaces which were partly erected several years ago, but upon which work had been indefinitely suspended. The annual capacity of the 549 completed and the 28 building and partly erected open-hearth furnaces, in ingots and direct castings, in June, 1904, was 11,335,100 gross tons, against an annual capacity in November, 1901, of 8,289,750 tons, showing an increase of 3,045,350 tons.

Growth of Basic Steel. — In the "Directory" we indicate the character of the product made at our open-hearth steel works whether acid or basic steel, or both. Of the 403 completed furnaces in November, 1901, 236 were prepared to make basic steel and 167 to make acid steel, and of the 46 building furnaces 33 would make basic steel and 13 acid steel. The completed and building basic furnaces had an annual capacity of 6,415,100 tons and the acid furnaces of 1,874,650 tons. In the present "Directory" 185 open-hearth furnaces are described as making acid steel and 364 as making basic steel; also four acid and 24 basic furnaces as being built or as partly erected; total, 189 acid and 388 basic furnaces. The acid furnaces have an annual capacity of 2,015,900 gross tons of ingots and castings, and the basic furnaces of 9,319,200 tons.

Crucible Steel Works. — In November, 1901, there were 45 completed crucible steel plants, equipped with 2,896 pots, and their aggregate capacity was 175,000 tons. In June, 1904, there were 57 completed plants, the number of pots was 3,606, and the aggregate annual capacity of the plants was 226,610 tons.

Steel Castings. — In 1901 there were 56 open-hearth steel plants which were prepared to make steel castings, and in June, 1904, there were 84 plants. The production of open-hearth steel castings has greatly increased since 1898. As already mentioned,

the number of small Bessemer plants has also increased since 1901, all of which make steel castings. Steel castings are also made by 26 crucible plants; also by a few plants which use special processes.

Rail Mills. — In the edition of the "Directory" for 1901 we enumerated 45 rolling mills which were prepared to make standard, girder, light *T,* and other iron and steel rails, and three mills as in course of erection. In the present edition we enumerate 44 completed rail mills, one building, and one projected.

Structural Mills. — The whole number of works which are now equipped to roll beams, beam girders, zee bars, tees, channels, angles, bridge rods, building rods, plates for bridge work, structural tubing, etc., is 70, as compared with 67 in November, 1901.

Plate and Sheet Mills. — In the "Directory" for 1901 we enumerated 153 completed plate and sheet mills, seven building, and one projected. In the present "Directory" we enumerate 157 completed mills, two building, one partly erected, and four projected.

Iron and Steel Skelp Mills. — In the "Directory" for 1901 we enumerated 60 completed iron and steel skelp mills and two building. We now enumerate 61 completed mills and two projected.

Black Plate Mills. — In the "Directory" for 1901 we enumerated 46 completed black plate plants, six building, and one projected. In the present "Directory" we mention 49 completed and three building plants.

Tinplate and Terne Plate Works. — In November, 1901, there were 55 completed tinplate and terne plate works, seven building, and one projected. In the present "Directory" we enumerate 53 completed works, two building, and one projected.

Wire Rods. — In November, 1901, we enumerated 32 completed wire-rod mills, four building, one rebuilding, and one projected. In June, 1904, there were 33 mills equipped to roll iron and steel wire rods.

Cut Nail Works. — In November, 1901, there were 32 rolling mills which were devoted in whole or part to the manufacture of cut nails and cut spikes, containing 3,161 nail and spike machines. In June, 1904, there were 23 rolling mills which made cut nails and cut spikes, equipped with 2,302 nail and spike machines. These were located in eight States, as follows: Massa-

chusetts, three; Pennsylvania, eight; Virginia, one; West Virginia, three; Kentucky, one; Ohio, four; Illinois, two, and California, one. In addition one cut-nail works was being built in Indiana, to be equipped with 102 cut-nail machines. The cut-nail works are fully described in the supplement to the "Directory" for 1901, published in 1903.

Wire Nail Works. — For a full description of the wire-nail works see the supplement to the "Directory" for 1901, published in 1903.

Natural Gas. — In the "Directory" for 1901 we enumerated 110 completed iron and steel works which used natural gas and seven in course of erection. In June, 1904, the total number of works which used natural gas was 135, and in addition two works to use natural gas were being erected, one works was partly erected, one works was rebuilding, and two works were projected, as follows: Fifty-four completed in Allegheny county and 33 completed and one projected in other parts of Western Pennsylvania; West Virginia, 11 completed and two building; Kentucky, one; Ohio, 19 completed, one partly erected, and one projected; Indiana, 16 completed and one rebuilding; and Illinois, one.

Forges and Bloomaries. — The number of pig and scrap iron bloomaries which made blooms, billets, etc., for sale in November, 1901, was eight, nearly all of which were active in that year. The number of forges which made blooms directly from the ore was two. The number of bloomaries now enumerated is eight completed and one building. The number of forges which make blooms directly from the ore is reduced to one, located in New York.

Canada. — In the edition for 1901 there was presented a complete description of the iron and steel works of Canada. As there have since been few and comparatively unimportant additions to these works it has not been thought necessary to revise for the present volume the Canadian information given in the "Directory" for 1901. J. M. S.

SUMMARY BY STATES.

BLAST FURNACES.

STATES.	Completed Furnaces, June 1, 1904.				Annual Capacity of Completed Furnaces, June 1, 1904, in gross tons.			
	Anthracite.*	Bituminous.	Charcoal.	Total.	Anthracite.*	Bituminous.	Charcoal.	Total—Gross tons.
Massachusetts,	....	....	2	2	....	....	9,000	9,000
Connecticut,	....	....	3	3	....	....	15,000	15,000
New York,	8	10	4	22	390,000	1,040,000	90,000	1,520,000
New Jersey,	7	5	....	12	151,000	395,000	....	546,000
Pennsylvania,	61	89	5	155	2,478,900	8,731,000	15,300	11,225,200
Maryland,	....	5	1	6	....	415,000	6,000	421,000
Virginia,	....	22	4	26	....	857,000	33,500	890,500
West Virginia,	....	4	....	4	....	425,000	....	425,000
Kentucky,	....	8	....	8	....	235,000	....	235,000
Tennessee,	....	19	3	22	....	787,000	26,600	813,600
North Carolina,	....	1	....	1	....	35,000	....	35,000
Georgia,	....	1	3	4	....	72,000	51,500	123,500
Alabama,	....	43	6	49	....	2,724,500	94,500	2,819,000
Texas,	....	....	4	4	....	....	72,500	72,500
Ohio,	....	54	7	61	....	5,226,000	30,700	5,256,700
Illinois,	....	22	....	22	....	2,275,000	....	2,275,000
Michigan,	....	1	10	11	....	90,000	304,000	394,000
Wisconsin,	....	5	1	6	....	310,000	45,000	355,000
Minnesota,	....	1	....	1	....	80,000	....	80,000
Missouri,	....	1	1	2	....	45,000	25,000	70,000
Colorado,	....	5	....	5	....	500,000	....	500,000
Washington,	....	....	1	1	....	....	18,000	18,000
Oregon,	....	....	1	1	....	....	15,000	15,000
Total,	76	296	56	428	3,019,900	24,242,500	851,600	28,114,000

* Includes 5 furnaces which use anthracite coal alone for fuel and 71 furnaces which use anthracite coal and coke mixed.

In addition to the furnaces enumerated above 2 furnaces in Virginia and 3 furnaces in West Virginia were equipped for the production by electricity of ferro-chrome, ferro-silicon, ferro-tungsten, and other ferro alloys.

On June 1, 1904, there were 17 furnaces in course of erection or being rebuilt, located in the following States: New York, 3 bituminous; Pennsylvania, 5 bituminous; Virginia, 1 bituminous; Alabama, 2 bituminous; Ohio, 4 bituminous; Michigan, 1 charcoal; and Colorado, 1 bituminous: total, 16 bituminous and 1 charcoal. In addition there were 8 furnaces which were projected, one of which was partly built and work on it indefinitely suspended, located in the following States: New Jersey, 1 anthracite alone; Pennsylvania, 1 anthracite and coke (partly erected); Alabama, 3 bituminous; Ohio, 1 bituminous; Missouri, 1 bituminous; and Utah, 1 charcoal and coke mixed.

SUMMARY BY STATES.

ROLLING MILLS, STEEL WORKS, TINPLATE WORKS, ETC.

States.	Completed Rolling Mills and Steel Works.	Completed Iron and Steel Rolling Mills.*	Cut-Nail and Cut-Spike Machines.	Steel Works. Bessemer.	Steel Works. Clapp-Griffiths.	Steel Works. Robert-Bessemer.	Steel Works. Tropenas and Special Bessemer.	Steel Works. Open-hearth.	Steel Works. Crucible.	Tinplate and Terne Plate Works.	Forges and Bloomaries.
Maine	1	1	....	....	....	....	....	....	....	....	....
Massachusetts	13	7	260	....	1	....	1	4	4	....	....
Rhode Island	4	3	....	....	....	....	1	1	....	....	....
Connecticut	9	6	....	....	....	....	....	3	2	....	....
New York	26	21	....	2	....	....	1	8	4	2	2
New Jersey	23	20	....	....	....	....	2	5	5	....	....
Pennsylvania	248	214	759	12	....	....	3	67	29	26	6
Delaware	7	6	....	....	....	....	....	2	....	....	....
Maryland	6	6	....	1	....	....	....	1	....	2	1
Dist. of Columbia	1	....	....	....	....	....	1	....	....	....	....
Virginia	6	5	137	1	....	....	1	....	....	1	....
West Virginia	16	15	353	2	....	....	....	1	....	5	....
Kentucky	10	10	126	1	....	....	....	1	....	1	....
Tennessee	2	1	....	....	....	....	....	1	1	....	....
Georgia	1	1	....	....	....	....	....	....	....	....	....
Alabama	13	11	....	1	....	....	....	5	....	....	....
Ohio	82	73	526	7	....	1	....	16	1	8	....
Indiana	36	29	....	....	....	....	....	6	1	4	....
Illinois	30	24	126	3	....	....	1	8	2	2	....
Michigan	5	4	....	....	....	1	....	....	....	1	....
Wisconsin	14	4	....	1	....	....	2	3	8	....	....
Minnesota	2	1	....	....	....	....	1	....	....	....	....
Missouri	5	4	....	....	....	....	....	1	....	1	....
Kansas	1	1	....	....	....	....	....	....	....	....	....
Colorado	2	2	....	1	....	....	....	1	....	....	....
Wyoming	1	1	....	....	....	....	....	....	....	....	....
Washington	1	1	....	....	....	....	....	....	....	....	....
Oregon	2	1	....	....	....	....	1	....	....	....	....
California	5	3	15	....	....	....	1	1	....	....	....
Total	572	475	2,302	32	1	2	16	135	57	53	9

* Excludes all steel works that do not contain hot trains of rolls.

On June 1, 1904, there were 12 rolling mills and steel works being erected in the United States, as follows: New York, 1; Pennsylvania, 2; Delaware, 1; West Virginia, 2; Alabama, 1; Ohio, 1; Indiana, 3; and Washington, 1. In addition 1 plant in Delaware was being rebuilt, and 1 plant in Pennsylvania and 1 plant in Ohio were partly erected but work upon their construction indefinitely suspended. Fourteen rolling mills and steel works were also projected, as follows: New York, 1; New Jersey, 1; Pennsylvania, 2; West Virginia, 1; Ohio, 3; Indiana, 1; Illinois, 1; Michigan, 1; Colorado, 1; Washington, 1; and California, 1.

On the same date 2 tinplate and terne plate works were being erected, as follows: West Virginia, 1, and Colorado, 1. In addition 1 plant for the manufacture of tinplates and terne plates was projected in Indiana.

One forge to manufacture charcoal blooms, slabs, and billets for its own consumption and for sale was being built on June 1, 1904.

SUMMARY BY STATES.

CAPACITIES OF ROLLING MILLS AND STEEL WORKS.

STATES— Gross tons.	Rolling Mills.* Number of completed works.	Rolling Mills.* Annual capacity of finished rolled products.	Bessemer Steel Works.† Number of converters.	Bessemer Steel Works.† Annual capacity of ingots and castings.	Open-hearth Steel Works.† Number of furnaces.	Open-hearth Steel Works.† Annual capacity of ingots and castings.	Crucible Steel Works. Number of completed works.	Crucible Steel Works. Annual capacity of ingots and castings.	Total annual capacity of ingots and castings, in gross tons.
Maine,	1	30,000	.....	....	.....	....	.....	....	....
Mass.,	7	255,100	2	31,200	14	214,000	4	1,750	246,950
Rhode Island,	3	78,000	2	2,500	2	20,000	.....	....	22,500
Connecticut,	6	177,500	.....	....	6	87,000	2	2,400	89,400
New York,	21	1,416,500	8	1,046,500	20	407,800	4	13,780	1,468,080
New Jersey,	20	584,300	5	7,500	15	215,000	5	28,200	250,700
Pennsylvania,	214	12,548,700	35	5,392,000	354	7,272,900	29	170,205	12,835,105
Delaware,	6	83,600	2	3,000	8	170,000	.....	....	173,000
Maryland,	6	515,000	3	500,000	2	35,000	.....	....	535,000
Dist. of Col.,	.....	....	1	300	.....	....	.....	....	300
Virginia,	5	172,700	3	61,000	.....	....	.....	....	61,000
West Virginia,	15	634,300	4	340,000	3	24,000	.....	....	364,000
Kentucky,	10	260,800	2	150,000	7	96,000	.....	....	246,000
Tennessee,	1	50,000	.....	....	1	500	1	300	800
Georgia,	1	20,000	.....	....	.....	....	.....	....	....
Alabama,	11	653,000	**1	....	19	531,100	.....	....	531,100
Ohio,	73	3,981,250	15	3,302,400	55	959,900	1	450	4,262,750
Indiana,	29	1,055,900	.....	....	14	203,500	1	100	203,600
Illinois,	24	2,080,000	10	2,088,000	42	841,000	2	3,500	2,932,500
Michigan,	4	97,000	2	5,000	.....	....	.....	....	5,000
Wisconsin,	4	329,000	5	95,000	3	9,400	8	5,925	110,325
Minnesota,	1	25,000	1	1,000	.....	....	.....	....	1,000
Missouri,	4	114,000	.....	....	5	40,000	.....	....	40,000
Kansas,	1	100,000	.....	....	.....	....	.....	....	....
Colorado,	2	610,000	2	600,000	6	200,000	.....	....	800,000
Wyoming,	1	18,000	.....	....	.....	....	.....	....	....
Washington,	1	24,000	.....	....	.....	....	.....	....	....
Oregon,	1	6,000	1	1,200	.....	....	.....	....	1,200
California,	3	58,400	1	2,000	1	8,000	.....	....	10,000
Total,	475	25,978,050	‖105	13,628,600	‡577	11,335,100	57	226,610	25,190,310

* Includes all completed rolling mills, but excludes all works not having hot rolls.

† Includes all completed, building, and partly built Bessemer and open-hearth plants.

‖ Includes 75 completed standard Bessemer steel converters with an annual capacity of 13,551,000 tons of ingots and castings, 1 Clapp-Griffiths converter with an annual capacity of 30,000 tons, 3 top-blown converters with an annual capacity of 2,500 tons, 14 Tropenas converters with an annual capacity of 20,500 tons, 2 Evans-Wills converters with an annual capacity of 5,000 tons, 1 completed and 2 building Bookwalter converters with an annual capacity of 6,000 tons, 3 Robert-Bessemer converters with an annual capacity of 7,400 tons, and 4 special converters with an annual capacity of 6,200 tons.

‡ Includes 189 completed, building, and partly erected acid open-hearth steel furnaces with an annual capacity of 2,015,900 gross tons of ingots and castings and 388 basic furnaces with an annual capacity of 9,319,200 tons of ingots and castings.

** Converter used for desiliconizing and decarburizing molten metal for the open-hearth furnaces of the Tennessee Coal, Iron, and Railroad Company.

GRAND SUMMARY.

NUMBER AND CAPACITY OF IRON AND STEEL WORKS.	June, 1904.	November, 1901.
Number of completed Blast Furnaces—296 Bituminous, 71 Anthracite and Coke, 5 Anthracite alone, and 56 Charcoal: total,	428	406
Number of Electric Furnaces,	5	....
Number of Blast Furnaces building and rebuilding,	17	12
Annual capacity of completed Blast Furnaces, gross tons,	28,114,000	24,812,037
Annual capacity of the Bituminous Furnaces, gross tons,	24,242,500	20,771,200
Annual capacity of the Anthracite and Anthracite and Coke Furnaces, gross tons,	3,019,900	3,190,087
Annual capacity of the Charcoal Furnaces, gross tons,	851,600	706,750
Annual capacity of the mixed Charcoal and Coke Furnaces,	....	144,000
Number of Completed Rolling Mills and Steel Works,	572	527
Number of Rolling Mills and Steel Works building and rebuilding,	13	29
Number of Single Puddling Furnaces, (a double furnace counting as two single furnaces,)	3,161	3,251
Number of Heating Furnaces,	3,995	3,723
Annual capacity in finished products of completed Rolling Mills, double turn, (omitting all forged products,)	25,978,050	23,220,350
Number of Cut-nail Works connected with rolling mills,	23	32
Number of Cut-nail Machines,	2,302	3,161
Number of completed standard Bessemer Steel Works,	32	35
Number of standard Bessemer Converters,	75	81
Annual capacity of these Converters (built and building) in ingots and direct castings, gross tons,	13,551,000	12,938,000
Number of completed Clapp-Griffiths Steel Works,	1	1
Number of completed Clapp-Griffiths Converters,	1	1
Number of completed Robert-Bessemer Steel Works,	2	2
Number of completed Robert-Bessemer Converters,	3	3
Number of completed Tropenas and Special Bessemer Steel Works,	16	9
Number of completed Tropenas and Special Bessemer Converters,	24	15
Annual capacity of all kinds of Bessemer Converters (built and building) in ingots and direct castings, gross tons,	13,628,600	12,998,700
Number of completed Open-Hearth Steel Works,	135	112
Number of Open-Hearth Steel Works building,	5	12
Number of Open-Hearth Steel Furnaces—549 completed, 22 building, and 6 partly built,	549	403
Annual capacity of these Furnaces (built, building, and partly erected) in ingots and direct castings, gross tons,	11,335,100	8,289,750
Number of completed Crucible Steel Works,	57	45
Number of building Crucible Steel Works,	....	3
Number of Steel-melting Pots in completed works,	3,606	2,896
Annual capacity of Pots in ingots and direct castings,	226,610	175,000
Number of completed Tinplate and Terne Plate Works,	53	55
Number of Tinplate and Terne Plate Works building,	2	7
Number of Forges making wrought iron from ore,	1	2
Annual capacity in blooms, double turn, gross tons,	6,000	6,075
Number of completed pig and scrap iron Bloomaries,	8	8
Number of building pig and scrap iron Bloomaries,	1	....
Annual capacity in blooms of completed and building pig and scrap iron Bloomaries, double turn, gross tons,	41,300	25,575

A NEW PROCESS FOR THE PROTECTION OF IRON AND STEEL FROM CORROSION*

By SHERARD COWPER-COLES

ZINC has proved the most effective coating for iron and steel, and hot galvanizing, with all its attendant disadvantages, is the process most extensively used for applying the zinc coating. Electro-zincing or cold galvanizing is used for special classes of work, and is extensively employed by the Admiralty for giving boiler tubes a thin flashing of zinc for the purpose of detecting flaws and protecting the tubes from corrosion during the time of assembling and erection. Works have just been completed for a new process to which the name of "Sherardizing" has been given. One point of particular interest about the new process is that iron and steel can be coated with an even deposit of zinc at a temperature of several hundreds of degrees below the melting-point of zinc.

The first step in the process is to free the iron from scale and oxide by any of the well-known methods, such as dipping in an acid solution or sand-blasting. The articles to be rendered rustless are then placed in a closed iron receptable, charged with zinc dust, which is heated to a temperature of from 500° to 600° F. for a few hours and allowed to cool; the drum is then opened and the iron articles removed, when they are found to be coated with a fine homogeneous covering of zinc, the thickness depending on the temperature and the length of time. It will be observed that the temperature required to bring about this result is about 200° below the melting-point of zinc. The low temperature required makes the process cheap as compared to the process of dipping in molten zinc, and has the additional advantage that it does not deteriorate iron or steel of small section to the same extent as hot galvanizing. The whole of the zinc dust is consumed; there is no waste of zinc as in the hot galvanizing process. This new process of galvanizing is not limited to the coating of iron with zinc, it has been successfully applied to coating iron with copper aluminium and antimony. It has also been applied to various other metals, for instance, aluminium and copper with zinc.

* "Electro-Chemist and Metallurgist," June, 1904; slightly abridged.

Copper and its alloys subjected to this process are case-hardened on the surface, and can be rendered so hard as to turn the edge of a steel tool.

The zinc powder used in the process is the zinc dust of commerce, and must not be confused with zinc oxide; it is obtained during the process of distilling zinc from its ores. Zinc dust at the present time is used for a variety of purposes, and can be obtained in any desired quantity. The average price of zinc dust for the year 1903 was £19 19*s.* per ton, which is slightly below the average price of virgin spelter. The analysis of two samples of zinc dust such as are employed for Sherardizing gave respectively 85 and 85.06 per cent and 81.86 per cent metallic zinc. Both samples, when examined under the microscope, seemed to contain small bright metallic beads, unevenly distributed through the dust, and it is probable that this may account for the different percentage given by analysis. One of the peculiar properties of zinc dust is that it cannot be smelted or reduced to the metallic form under ordinary conditions, even when heated to a very high temperature under considerable pressure. This property is very advantageous for the new process of dry galvanizing (Sherardizing), as it does away with the risk there might otherwise be of melting the finely-divided zinc by overheating the furnace. The receptacle in which the zinc dust is placed and heated is preferably air-tight and the air exhausted so as to prevent the formation of too much zinc oxide; or, if this is not feasible, it is advisable to add about three per cent of carbon in a very fine state of division. If the percentage of oxide is allowed to increase beyond certain limits it is found that the deposits become dull in appearance instead of having a bright metallic lustre, although good deposits of zinc can be obtained from zinc dust varying considerably in composition. To prevent the iron receptacle in which the process of Sherardizing is carried on from becoming coated with zinc, it is found advantageous to coat the inside of the drum with plumbago or black lead. Articles coated with grease receive as good, if not a better coating of zinc than those which are free from grease. This fact is of considerable importance, as it enables machined work, such as bolts, nuts, screws, etc., to be thrown direct after machining into the Sherardizing drum without any preparation or cleaning. The articles when they have been heated in the zinc dust for the period necessary to obtain the thickness of zinc required, can be

removed whilst the zinc dust is still hot, although the better practice is to allow the zinc dust to cool to a temperature at which the articles can be readily handled, as the deposit of zinc is whiter and less oxide of zinc is formed. The new process of dry galvanizing offers many facilities and great economy to those manufacturers who have not sufficient work to keep a large bath of molten zinc continuously at work. Articles can be Sherardized at a few hour's notice, starting all cold, as the drums can readily

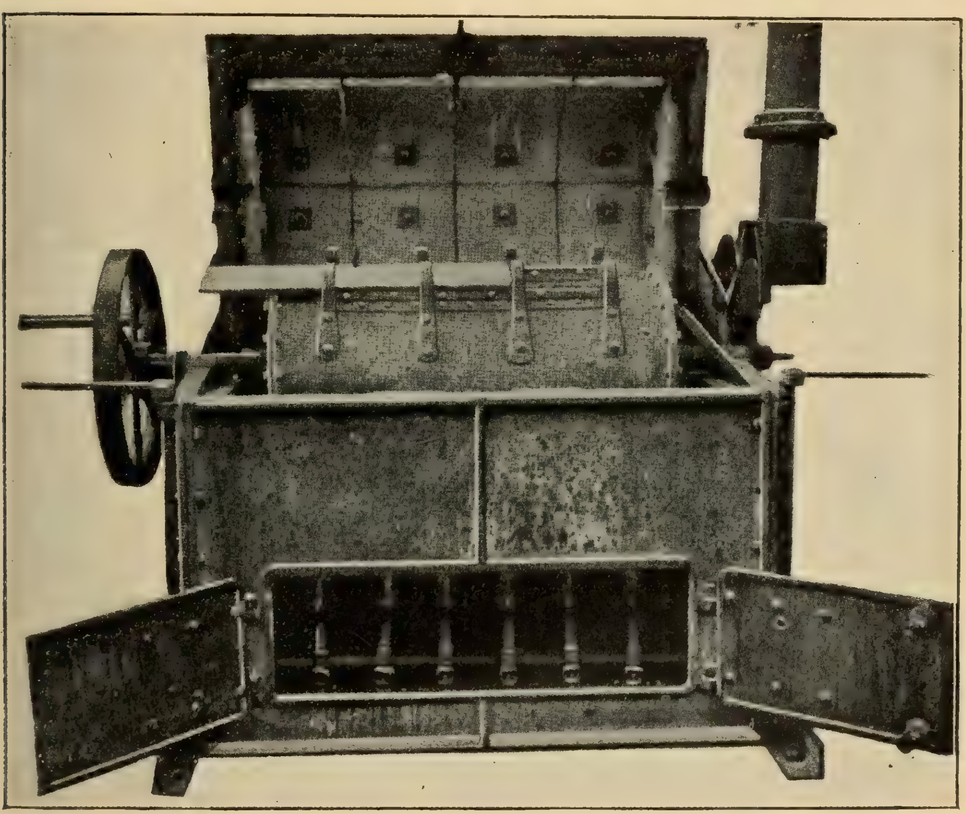

Fig. 1. Gas Furnace for Sherardizing Small Articles.

be heated by gas or coke furnaces, the whole operation occupying only a few hours. When the plant is not at work, there is no waste as in the case of hot galvanizing, when the zinc has to be kept in a molten condition day and night.

A useful type of furnace for small work consists of a closed iron chamber in the form of a cylinder or polygon, and arranged to be rotated or oscillated about its axis. The chamber is provided with an iron door either at one end or at the side, depend-

ing upon the class of articles to be treated; a side door is found to be the most suitable for small articles such as bolts, nuts, small castings, etc., and the end doors for tubes, oblong or cylindrical articles. In the latter case the cylinder is oscillated and rotated on its axis; in the former case it is rotated and provided with baffle plates to ensure the articles under treatment being turned over and thus becoming uniformly coated by bringing all parts into intimate contact with the zinc dust. Fig. 1 shows a furnace suitable for Sherardizing one or two cwt. of small articles at a

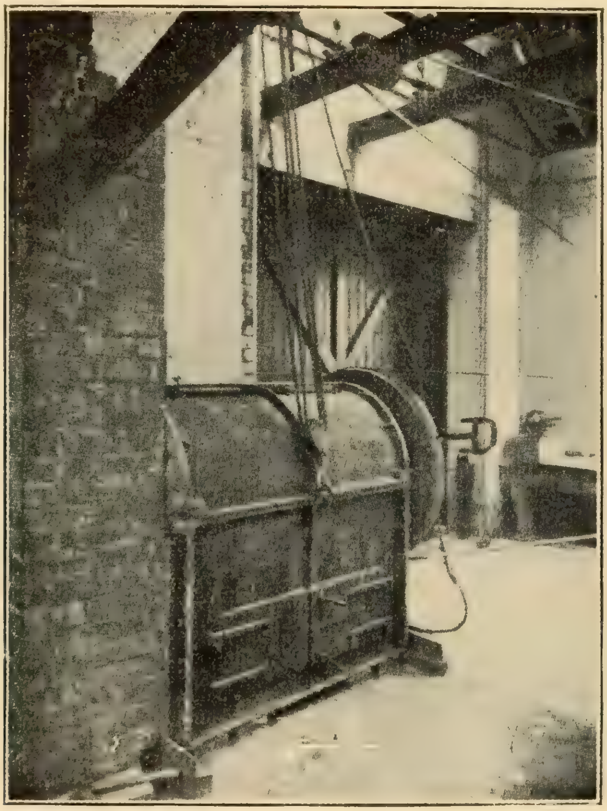

Fig. 2. Gas Furnace for Sherardizing Small Articles.

time; one of the trunnions is made hollow so that a pyrometer can be inserted. Below the furnace is arranged a number of Bunsen gas burners for heating the drum, and the whole is enclosed in a cast-iron shell lined with fire-brick. The drum can be rotated either by hand intermittently or continuously by means of a suitable gearing D, as shown in Fig. 2, which illustrates a similar construction of drum. The plant required for Sherardizing all classes of work must of necessity be modified to suit the dif-

ferent classes of work; for instance, if it is required to Sherardize an expanding gate or girder, an iron box would be used which would be kept stationary during the process of Sherardizing, the gate being opened to its full extent during the operation. Tubes require a different construction of drum to the drum required for bolts and nuts, wire and sheets also require modified arrangements to enable the work to be handled expeditiously. Fig. 3 shows the general arrangement of a Sherardizing plant which has recently been completed, comprising four furnaces which are

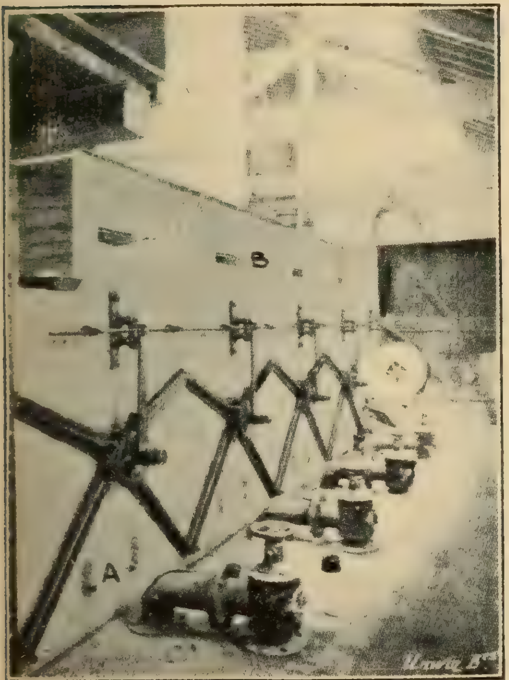

Fig. 4. Gear for Rotating Drums in Furnace.

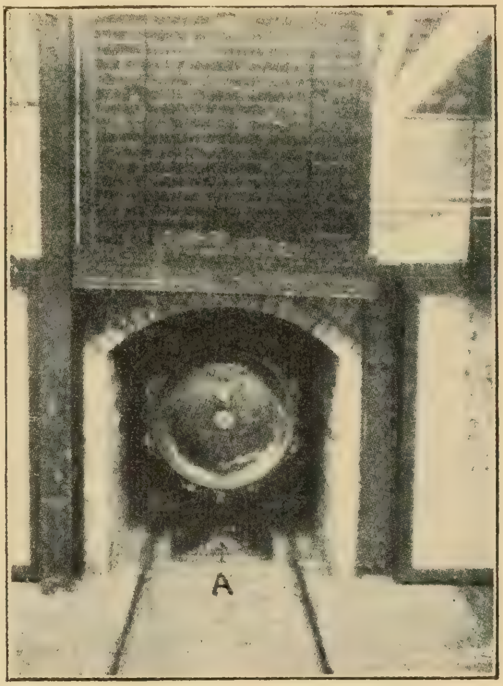

Fig. 5. Furnace with Drum in Position.

capable of taking drums of 8 ft. by 2 ft. with a cubic capacity of two tons of material at a charge; the weight of iron capable of being Sherardized per charge depending on how close the articles pack. The furnaces are heated by Dowson gas; the gas is led by iron pipes to the back of the furnaces, the supply of gas being controlled by iron cocks as shown in Fig. 4; the gas is then conducted through brick channels through which the air is drawn through the inlets A, the gas being burnt through cast-iron burners A, as shown in Fig. 4. The arrangement for rotating the

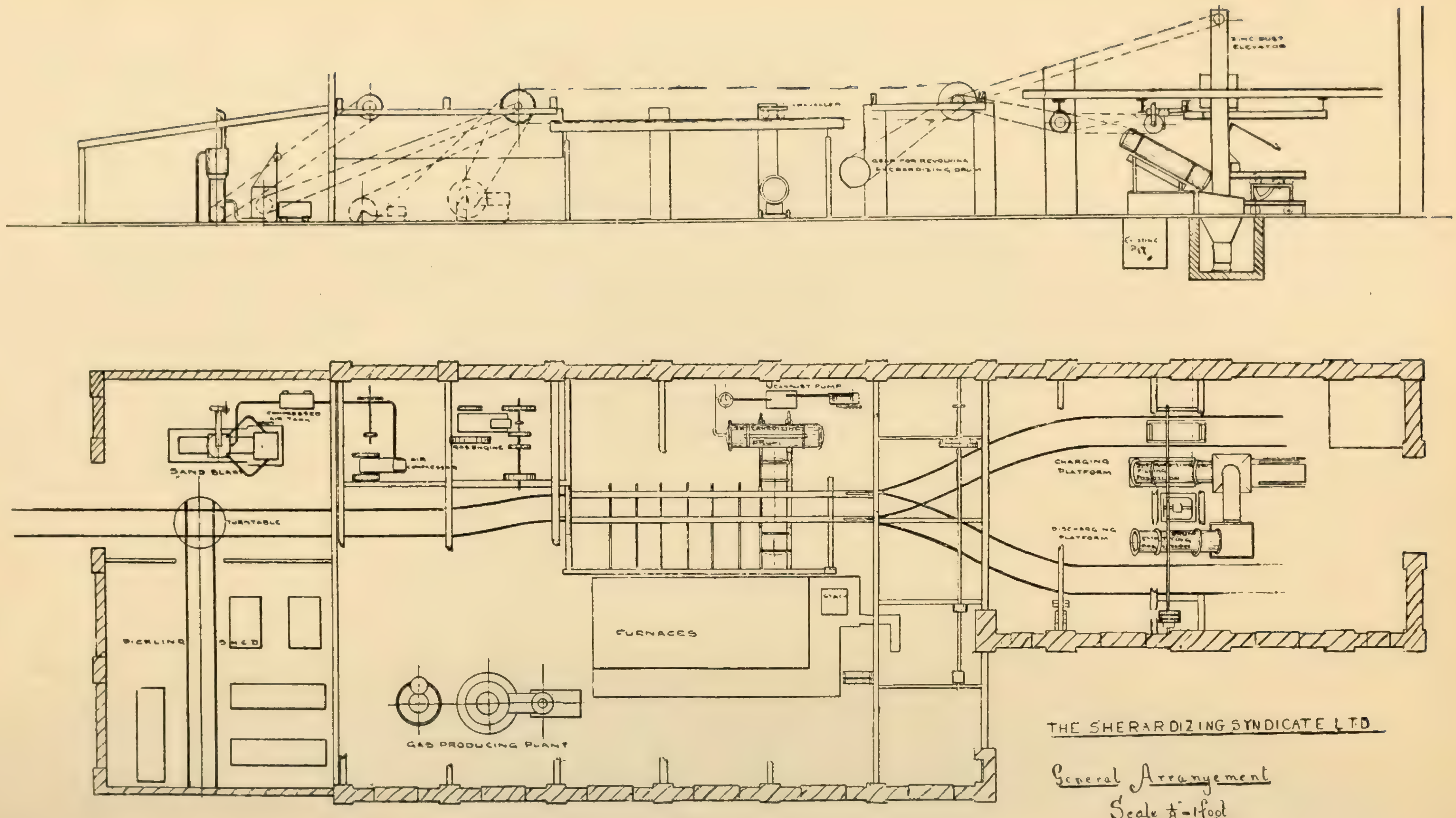
ZINC DUST ELEVATOR
GEAR FOR REVOLVING SHERARDIZING DRUM
EXHAUST PUMP
CHARGING PLATFORM
DISCHARGING PLATFORM
SAND BLAST
COMPRESSED AIR TANK
GAS ENGINE
AIR COMPRESSOR
TURNTABLE
PICKLING SHED
FURNACES
STACK
GAS PRODUCING PLANT
THE SHERARDIZING SYNDICATE LTD
General Arrangement

Fig. 3.

drums is also shown in Fig. 5, and consists of a pawl-and-rachet movement.

The charging of the drum is effected by running the truck on which the drum is placed on to a table, one end of which is lowered by means of gearing so as to tilt the other end into which the zinc dust is charged from an upper floor by means of a chute, as shown in Fig. 7, which illustrates a drum being discharged over an iron grating, which allows the zinc to fall into a chamber below, from which it is raised by means of a chain elevator to the

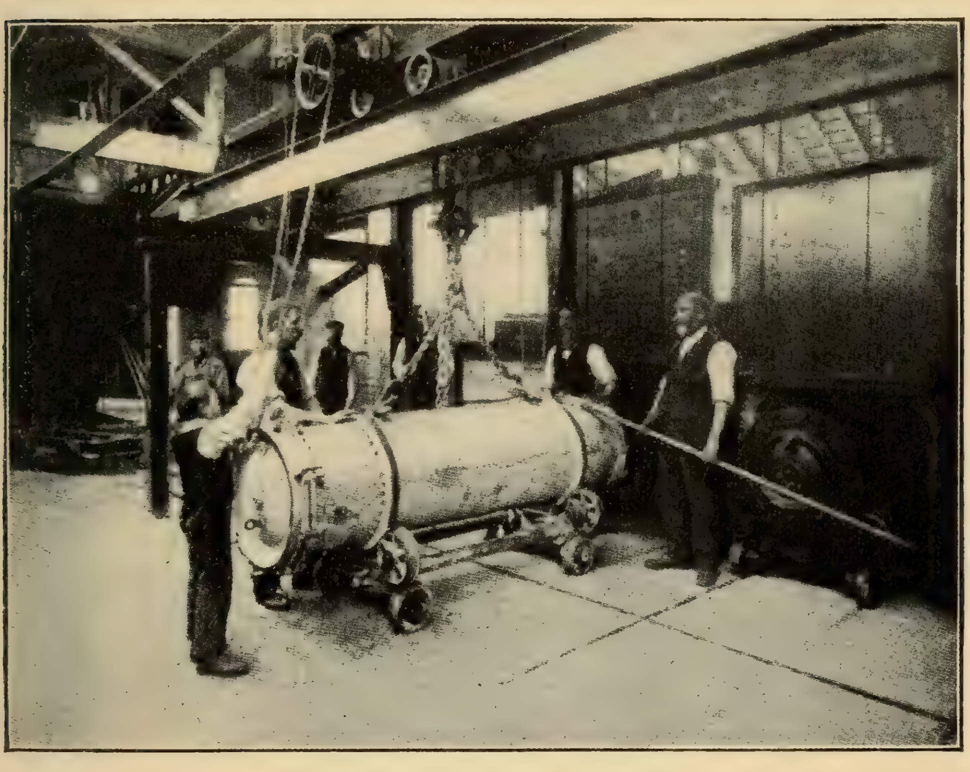

Fig. 6. Drum on Furnace Track.

floor above. When the drum is charged with zinc dust and the articles to be Sherardized, it is brought into a horizontal position, the air is exhausted, and the truck is run along the lines until it arrives in front of the furnaces. It is then lifted on to a furnace truck (Fig. 6), the object being to effect a saving in the first cost of the furnace and to save waste of heat. The drum is then pushed into the furnace, the door lowered, and the furnace heated up to the desired temperature. The heat is regulated in accordance with the readings of a thermometer, which is placed in a

vertical iron tube inside the furnace. When the drum has been in the furnace a sufficient time to give the desired result, the door is then raised and the drum and carriage withdrawn; the drum is lifted on to another carriage and run out into an open yard, where it is allowed to cool down to a temperature low enough to admit of handling.

The comparison of the surfaces obtained by hot and cold galvanizing and Sherardizing is different in each case, but they

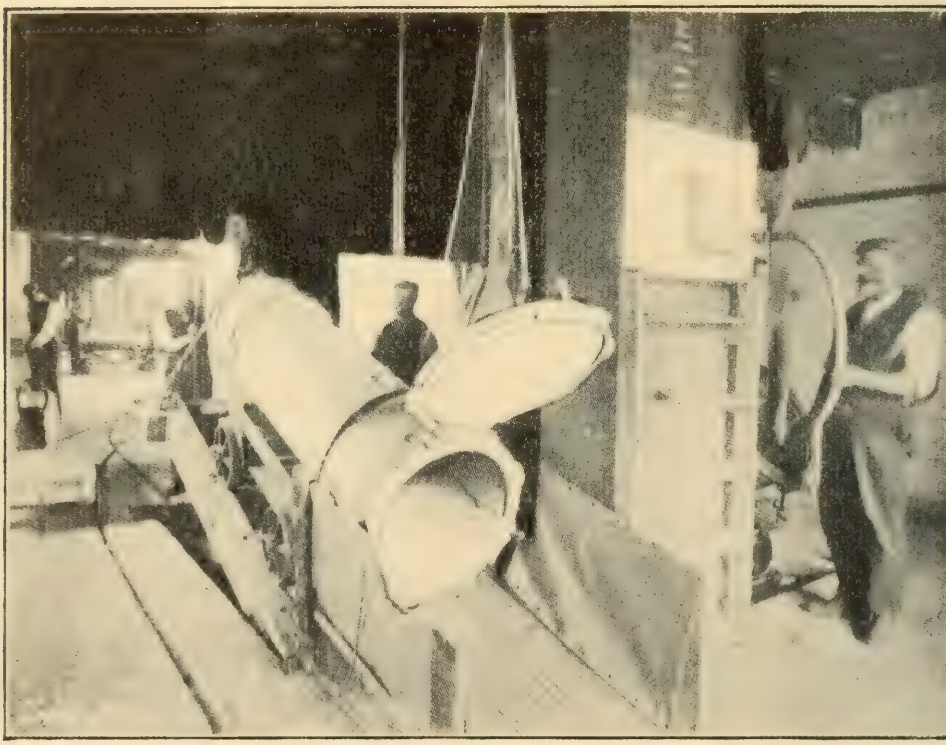

Fig. 7. Drum on Charging and Discharging Platforms.

can readily be distinguished by anybody conversant with the three processes. In the case of hot galvanizing, the surface is spangled, or has the appearance of cast-metal. In the case of cold galvanizing, the surface is free from spangles and has a matte or frosted surface, uniform if the work has been well executed. Sherardizing is again distinctive from the two former processes; the general appearance resembles more that of cold galvanizing than hot galvanizing, but is more lustrous and metallic, and is uniformly distributed over the whole surface, which is not the case with the hot and cold galvanizing processes. The

Dimensions.	Area square inches.	Extension. Reduction of area at fracture.	Extension. On 2 in.	Extension. On 2 in. at fracture.	On Original Area. Elastic Limit (Yields point) Pounds.	Elastic Limit (Yields point) Tons.	Maximum Stress. Pounds.	Maximum Stress. Tons.	Remarks.
		Per cent.	Per cent.	Per cent.	Per sq. inch.	Per sq. inch.	Per sq. inch.	Per sq. inch.	
Untreated Steel Rod 0·276 × 0·277	0·0774	—	1·0	—	70,358	31·41	121,676	54·32	Irregular fractures, broke outside datum points in jaws.
,, ,, ,, 0·274 × 0·274	0·0750	6·6	3·0	—	49,280	22·0	150,796	67·32	Broke outside datum points in jaws.
,, ,, ,, 0·278 × 0·278	0·0772	—	3·5	—	73,987	33·03	149,408	66·70	Irregular fracture, broke outside datum points in jaws.
,, ,, ,, 0·283 × 0·268	0·0758	3·7	3·0	—	69,440	31·00	153,932	68·72	Broke outside datum points in jaws.
Sherardized ,, ,, 0·279 × 0·285	0·0795	19·9	7·0	—	113,545	50·69	156,598	69·91	
,, ,, ,, 0·274 × 0·279	0·0764	6·7	4·0	—	102,032	45·55	148,064	66·10	Steel rods treated.
,, ,, ,, 0·274 × 0·283	0·0775	15·9	6·0	—	Not observable		154,918	69·16	
,, ,, ,, 0·276 × 0·284	0·0783	4·8	3·5	—	108,147	48·28	149,632	66·80	Broke outside datum points in jaws.

Sherardizing process, although similar to cold galvanizing in some respects, is also similar to hot galvanizing in other respects, inasmuch as the zinc alloys with the iron and forms a protective zinc-iron alloy intermediate between the zinc coating and the underlying metal.

As Sherardizing is effected at a very much lower temperature than hot galvanizing, the temper of steel wire is not reduced as it is in the latter process. A number of steel and iron bolts Sherardized at varying temperatures when tested for tensile strength were found to be equal in strength to bolts which had not been Sherardized. The table on the preceding page gives the results of tests for tensile strength upon four untreated and four treated Sherardized specimens of steel rod.

In practice, Sherardized iron and steel is found to withstand the ordinary corrosive agents to which galvanized iron is exposed to a remarkable degree; even after the apparent removal of all the zinc by filing or abrasion the iron is still non-corrosive. This valuable property is doubtless due to the protective action of the zinc iron alloy formed on the boundary line between the iron and zinc.

The dry process of galvanizing is cheaper than hot galvanizing for the following reasons:

(*a*) Less zinc is required to give the same protective coating, as the zinc is evenly distributed. (*b*) The temperature required is low. (*c*) The labor is less, as the articles do not require to be cleaned as carefully as in hot galvanizing. (*d*) No flux is required, no dross or skimmings are formed. (*e*) There is no danger of explosion or breaking of castings and distorting of thin iron work. (*f*) Sherardizing machine-work does not require refitting, as the coating is evenly distributed. (*g*) There is no reduction in tensile strength as in the case of hot galvanizing. (*h*) The coating is more uniform and even than that obtained by hot or cold galvanizing. (*i*) The work can be placed direct in the Sherardizing drum from the pickling vat without drying. (*j*) The process can be worked intermittently without waste. (*k*) Iron can be coated with zinc to any desired thickness.

Another advantage of Sherardizing, provided sufficient time is given for coating, is that it has the effect of bringing the surface into a more uniform state of tension. The cost of the plant for Sherardizing is very much cheaper than a plant of equal capacity for hot or cold galvanizing.

CHEMICAL CHARACTERISTICS OF LIMONITE (BROWN HEMATITE) IRON ORES*

By F. LYNWOOD GARRISON

THE precise chemical nature of the limonite ores in the Paleozoic rocks of the Appalachian system appears to be by no means simple or entirely understood. The name brown hematite so often applied to them is misleading, since a hematite is, strictly speaking, an anhydrous oxide (Fe_2O_3) whereas these ores are hydrous and should be genetically considered as limonite, having the formula according to Groth of $Fe_4O_3[OH]_6$. Groth† also uses the term "hydro-hematite," giving its formula as $Fe_4O_3[OH]_2$. The formula for limonite is often written $2Fe_2O_3.3H_2O$ which appears to be the most satisfactory construction. The older mineralogists used the expression red or brown hematite indistinguishably for both limonite and turgite ($2Fe_2O_3.H_2O$) or mixtures of the two. Groth considers turgite and hydrohematite as one and the same thing.‡

It would be much better if the name hematite could be restricted to the anhydrous oxide, and limonite to the hydrous. In coining the word limonite, Hausmann evidently applied it to ores found in valley bottoms or basins that were formerly lakes or swamps, since it is derived from the Greek *leimo,* a meadow. Though valleys and basins are probably a necessary condition to the accumulation of limonite ores, they are frequently found in the sides and tops of mountains, having been so elevated by dynamic action and changes subsequent to their deposition.

Instead of the confusing term brown hematite, the Germans call these ores *brauneisenerz,* that is, brown iron ore, a good distinctive and characteristic name. It is senseless to call ores found on a mountain (so called mountain ores) brown hematite and those in the valley limonite when the general chemical composition is the same. It is often true the mountain ores have been, at least in part, dehydrated, and are actually hematite; they have the characteristics of this mineral and are easily distinguished from limonite.

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* "Engineering and Mining Journal," August 18, 1904.

† "Tabellarische Uebersicht Mineralien" (1889), page 43.

‡ *Ibid,* page 43.

It is clear to even the casual observer that the limonite ores of the Appalachians are quite variable in their composition. Genth* long ago pointed out that such ores in Pennsylvania were distinct mechanical mixtures of a number of different minerals, the limonite of course greatly predominating. They are chiefly compounds or associations of limonite with hydrous ferric silicates. Genth found it impossible to determine the actual character of the accompanying silicate, whether anthrosiderite ($2Fe_2O_3.\ 9SiO_2.\ 2H_2O$) or degeroite ($Fe_2O_3.\ 2SiO_2.\ 3H_2O$). Hopkins observes that this silicate might be one of several of which chloropal ($Fe_2O_3.\ 3SiO_2.\ 5H_2O$) is a common form.†

The name limonite was first applied especially to bog ores by Hausmann in 1813. In 1832 Beudant used the name in connection with bog ores as well as others of a similar nature.

The hydrated ferric oxide itself commonly exists in nature in a dual form as a crystalline mineral, goethite, composed of one part iron oxide to one of water, i.e., $Fe_2O_3\ H_2O$, with a specific gravity of 4.4 and the amorphous variety limonite, whose specific gravity varies from 3.6 to 4.

Some of the ores also contain greater or less quantities of manganese, mostly in the condition of the so-called bog manganese or wad ($MnO + 5H_2O$) also pyrolusite ($Mn\ O_2$) and psilomelane ($(Mn\ Ba\ K_2)_5\ O_9 + H_2O$.‡ Between the extremes of pure iron ore and pure manganese ore, if in fact such can be said to exist in either case, are numerous gradations of chemically and mechanically mixed oxides of iron and manganese, the iron oxides vastly predominating; in fact, manganese preponderates only in sporadic occurrences, and seldom or never in any considerable quantity. This condition characteries the ores of Shady Valley, Tennessee, and can be accepted as a general rule for nearly the entire Appalachian system, though of course exceptions, such as the notable one at Crimora, Virginia, do exist. This fact would seem, in some degree, to be the explanation for the numerous failures to develop such manganese deposits into paying mining

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* "Second Geological Survey of Pennsylvania," Vol. 874, pages 46, 48, 52, 143, 144, 149.

† "Bulletin of the Geological Survey of America," Vol. XI, page 480.

‡ "This formula is sometimes constructed ($BaO\ MnO\ K_2O$) $MnO_2 + Mn_2O_3 + H_2O$.

propositions. Frequently what, on the surface, appear to be good deposits of manganese ore, are found upon development to represent only mere incrustations of manganese oxides upon iron ore, which may or may not be of value as an iron deposit, but they are pretty certain to be absolutely worthless as a manganese mine. The earthy manganese oxide wad is apt to be misleading; it imparts a black color to the clays near the ore-bodies, giving the impression of the presence of manganese in quantity, which is seldom the case since the black material is nearly all removed in the washing, leaving a clear iron ore containing perhaps very little manganese, unless the iron be combined chemically, mechanically, or both, with pyrolusite. In such a case, there may be sufficient manganese oxide present to unfit the ore for the manufacture of foundry iron, but rarely too much for basic pig.

Hopkins has computed the hypothetical combination of the various minerals found with limonite from a number of different localities in Pennsylvania. He assumes that the phosphorus unites with the alumina to form the mineral wavellite, which is highly probable, and that it also combines with the iron to form vivianite, the silica coalescing with the iron as grünerite. If one of the hydrous ferric silicates is formed, the proportions would be slightly changed, as shown in the third combination. After forming the wavellite, the remaining alumina is in the form of kaolin, and the remaining water and iron are combined so as to form all the limonite possible and the iron in excess is put into goethite, the next highest oxide.*

1	Per Cent	2	Per Cent
Limonite, $Fe_2O_33H_2O$	77.79	Limonite	75.65
Goethite, $Fe_2O_3H_2O$	8.07	Goethite	9.61
Grünerite, $FeSiO_3$	8.40	Grünerite	8.59
Wavellite	0.78	Vivianite	1.95
Kaolin	1.30	Kaolin	8.70

If the silica is combined with the iron in the form of anthosiderite, it will be seen that the remaining iron and water in No. 5 will be in the proper ratio to form limonite, and hence this seems a probable combination:

* "Bulletin of the Geological Society of America," Vol. XI., page 482.

Hypothetical Combinations of the Elements in the Limonite Ores

Computing the excess of silica as anthosiderite:

	No. 5	No. 1	No. 2	No. 6
Limonite	92.80	65.72	54.23	44.51
Goethite	....	23.49	39.95	44.70
Anthosiderite	5.91	4.05	4.06	2.39
Wavellite	0.39	0.993	0.45	0.76
Kaolin	0.77	1.29	0.26	3.61
Quartz	....	2.60	0.44	0.44
$Fe_2O_3:H_2O$ (molecular)	496:747	478:652	515:660	506:625
	2:3 nearly limonite	3:4 nearly	4:5 nearly	4:5 nearly

Computing the excess silica as chloropal:

Limonite	63.60	34.78	36.85	33.66
Goethite	26.52	50.73	59.10	57.85
Chloropal	8.60	8.62	5.92	3.01
Wavellite	0.39	0.99	0.45	0.76
Kaolin	0.77	1.29	0.26	3.61
Quartz	....	2.60	0.44	0.44
$Fe_2O_3:H_2O$ (molecular)	489:660	471:564	510:599	505:595
	3:4 nearly	4:5 nearly	5:6 nearly	5:6 nearly

but in Nos. 1, 2 and 6 the iron and water are in the proportion of 3:4 and 4:5. If chloropal is formed, the iron water ratio is 3:4, 4:5 and 5:6. It is possible that iron and water may combine in these variable ratios; but until it can be proven in some way, it seems better to consider them as forming mixtures of the established compounds, limonite and goethite or turgite.

It is certain some silica enters into chemical combination with the iron but the greater part of it is simply mechanically united in fine particles. Similarly minute specks of clay are thrown down with the iron precipitate, forming a very close association with the ore which cannot all be removed by washing.

It is evident the same solutions that carry the iron also contain silica in solution which may or may not be deposited along with the iron according to the presence or absence of conditions not as yet entirely understood. In the Shady Valley deposits the clays are full of irregular, angular grains of silica, also many perfectly formed, and often doubly terminated quartz crystals. That waters carrying iron have a strong solvent action on silica is

shown by the dissolution of the chert, chale and sandstone fragments found in the ore masses and breccias.

Other iron minerals are often present with the limonite, such as ilmenite $(TiFe)_2O_3$, siderite $(FeCO_3)$ and iron pyrite (FS_2). In considering the genesis of the limonite ores, it will be seen how significant the presence of siderite and pyrite may be in this connection as an evidence of the source of the iron, or at least a step in the evolution of the limonite deposits.

THE STRUCTURE OF HIGH-SPEED STEELS*

ALTHOUGH high-speed steels have sprung into popularity with surprising suddenness; although much has been written about their use and something about their manufacture, little has been heard as to the causes which give them their astonishing properties. We turn, therefore, with no small amount of interest to two papers which appear in the current " Bulletin de la Société d'Encouragement pour l'Industrie Nationale," one by Le Chatelier and the other by Osmond, which promise us some light on this subject. These gentlemen hold such an exalted position in the field of scientific metallurgy that we must give close attention to whatever they have to tell us.

It is, then, disappointing to find that the explanations they offer are only tentative, and, in Osmond's case, not even based on actual commercial high-speed steel, which he has not examined, but only on specimens of chrome and tungsten steels, which he assumes to possess the same nature. We are far from saying that he is not right in this assumption, since we can ask for no more capable judge of such matters; but it is impossible, when we remember the remarkable effect that minute quantities of certain ingredients have on alloys, not to regret that the examinations on which his theory is founded are not based on actual samples of such metals as are used daily in manufacturing works. However, leaving that to one side, the explanation Osmond has to offer is simple and up to a certain point convincing. No new theory he

* " The Engineer," July 22, 1904.

tells us is required, only a slight addition to that of the hardening of ordinary carbon steel. "To render the general theory of carbon steels immediately applicable, it is sufficient to take account of the fact that the separation of carbide during cooling and its corresponding solution during heating are rendered difficult by the presence of chromium, tungsten, or other substances." Hence the changes in the constitution take place slowly, and we need not adopt such a sudden method of arresting them at any particular stage as when we plunge ordinary carbon steel into water. It is sufficient to cool the tungsten steel slowly to obtain the same end. Put in another way, whereas we must use powder and shot to stop the hare, we may roll a ball fast enough to strike the tortoise. If such an explanation as this on further examination should be proved to hold good, it is entirely admirable for its simplicity. It, too, may be taken to explain the extraordinary fact that such steels cut well at temperatures which would soften ordinary tool steels. The reason the latter fail is that at the temperature reached the particular condition obtaining at the instant they were petrified by being suddenly chilled is destroyed; but with tungsten steels the brakes, so to speak, are hard on all the time. The change takes place slowly instead of rapidly, and, in place of the rapid softening at the edge which occurs with ordinary steel, a comparatively long period of subjection to the high temperature is necessary. This, combined with the fact that the changes do not occur until a fairly elevated temperature has been reached, gives us an explanation of why high-speed steels will cut at a dark red heat. Le Chatelier tells us that such steels will stand 500° to 600° C., "at least for a certain time," and that it requires the application of 700° for an hour to soften them completely. We may add to this that Osmond seems disposed to accept a suggestion of Le Chatelier's that the high temperature that must be reached to restore the qualities of tungsten steels is due to the fact that at this point "austenite transforms itself into martensite," and that hardening takes place instead of the softening to which one is habituated by ordinary carbon steels — a suggestive, if not a very satisfactory, explanation of their peculiar cutting properties.

Whilst Osmond has little or nothing to say about practical applications, Le Chatelier gives more attention to them than to questions of constitution. He urges, very rightly, a point which

we believe has been thoroughly well grasped in this country, and which is testified to by the extraordinary success of British high-speed steels. It is, of course, the necessity for exactness, in manufacture — exactness in the apportionment of the ingredients and precision in the temperatures used in treatment, but he makes the curious reflection on the ease with which self-hardening steels are treated that it rather hinders progress, since that delicacy of manipulation, which he believes will some day be required when the highest duty is sought, is not now demanded. That is a point of view that will certainly not appeal to foremen and managers whose objection to the Taylor-White steel was that it could not be treated in their own shops, and whose preference for our English steels is that one may do pretty well what he wills with them, from not treating them at all to treating them badly, and they will still behave at least fairly well. We have ourselves subjected a well-known brand to such various tests as cooling in air, cooling in a blast, plunging in water from a high temperature, and hardening in oil, and it has not injured it, and we have taken a piece of the same steel from the center of a square bar some six feet or seven feet long, ground it to an angle, and used without treatment at all; we have tried it wet and dry, and nearly red hot, and got equal results from it, and we think nearly all managers would agree with us that the ideal, from their point of view, is a steel of this order that they can hardly destroy by any treatment, and that can be used for any purpose. The former condition is nearly reached — the steel is not necessarily destroyed by bad treatment, but its highest results are not attained — but the latter is still far from attainment since no single steel is equally good for cast iron and steel. No brand, we believe we are right in saying, possibly with the exception of some drills, will do equally well on a casting as on a forging, on brittle cast iron as on ductile steel. That is a curious fact that would demand closer attention, if it were not that brands particularly suitable for each purpose are readily obtained.

STRUCTURAL STEEL*

THE enormous growth, during late years, in the use of metal for the construction of bridges, roofs, buildings, etc., led to the production of the material known as "structural" steel, which is now manufactured with an exactitude, as to ultimate strength, percentage of elongation, and chemical properties, little short of marvelous. In the early days of the manufacture of such steel, many were the efforts put forth to produce it commercially of a quality that could be relied upon to vary only a very small percentage from a specified standard; the standard aimed at being generally an ultimate tensile strength of from 27 tons to 28 tons per square inch, with a percentage of elongation of from 20 per cent to 25 per cent in a length of 8 inches; but it was a considerable time before the material could be made with sufficient regularity to satisfy careful engineers. At the present day there is no difficulty in producing structural steel with an exactitude as to quality that leaves little to be desired. When the industry was in its infancy, low carbon steel was, as is well known, chiefly made by the Bessemer process; but in a few years this was largely superseded by the Siemens-Martin open-hearth acid process, which now, together with the basic open-hearth process, is employed in producing the larger proportion of the steel used in the construction of bridges and similar works.

When mild steel began to take the place of iron, engineers were inclined, naturally enough, to view the new arrival with a certain amount of suspicion, and to adopt it with all the caution typical of a conservative class. Some of the bolder spirits welcomed it with satisfaction, if not with joy; while others, less sanguine, clung to wrought iron with a tenacity worthy of a better cause. In the early days of the use of mild steel the cautious men were, perhaps, not altogether without justification, because, as before stated, the material available did not prove altogether faultless, with the result that many members of the profession refused to adopt it, and left their more enterprising brethren to bear the responsibility of what they themselves considered doubtful experiments. We may, in fact, say, in justice to those engineers who moved at the slower pace, that the earlier

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* "Engineering," July 22, 1904.

mild steels were apt to vary in their chemical and physical properties in a way that was certainly not calculated to inspire absolute trust in their behavior, unless their use was accompanied by very careful selection and inspection.

Although British and Continental engineers have, since the use of mild steel commenced, chiefly employed only one grade of the material, such has not been the case in America, where, until quite recently, two grades — viz., soft steel and medium steel — were almost universally specified by engineers, the grade selected depending, of course, on the special duty which the steel had to perform. If we look through the specifications for structural steel drawn up by any of the leading American engineers, or bridge-builders, we find that the two grades — soft and medium — are always mentioned, and are used for distinct purposes, in a way which points to a strong faith in their different qualifications. Take, for instance, the American Bridge Company's general specifications for steel highway bridges. In this there are both soft and mild steel specified, and, in addition, a quality of steel of an extra ductile quality, to be used for rivets. For soft steel the ultimate strength ranges from 52,000 pounds to 62,000 pounds per square inch, with an elongation 25 per cent in 8 inches, and it is required that a test-piece shall stand bending 180° flat on itself without fracture. For medium steel the ultimate strength is fixed at from 60,000 pounds to 70,000 pounds per square inch, the elongation 22 per cent and the bending test 180° to a diameter equal to the thickness of the test piece without fracture on the outside of the bent portion. For rivet steel an ultimate strength of 48,000 pounds to 58,000 pounds per square inch is specified, with an elongation 26 per cent in 8 inches, and a bending test of 180° flat on itself, without fracture on the outside of the bent portion.

Now in English practice there is usually only one grade of steel used for structural purposes, and that grade corresponds very closely with the "medium" steel used in America; it is specified to have an ultimate tensile strength of from 27 to 32 tons per square inch, with an elongation, measured in a length of 8 inches, of not less than 20 per cent. It is also usual to specify a bending test, such that a specimen piece shall, when heated to a cherry red and cooled in water having a temperature of 82° F., bear bending double, when cold, round a curve, the diameter of

which is not more than one-and-a-half times the thickness of the piece, without showing any signs of fracture. Rivet steel is, as in America, usually specified of a softer kind, and must have an ultimate tensile strength of from 26 to 30 tons per square inch. It must also be capable, when cold, of being bent double on itself without showing signs of fracture.

Of late years a feeling has grown up among American engineers that the " soft steel " usually mentioned in their specifications might very well be omitted, because the limits mentioned for the two classes of steel — both " soft " and " medium " — always overlapped in the higher limit for the " soft " steel and the lower one for the " medium," and because both grades of steel could be made from the same ingot, and were practically alike. The American Bridge Company fix the limit for soft steel at from 52,000 pounds per square inch ultimate tensile strength to 62,000 pounds, and for " medium " steel from 60,000 pounds to 70,000 pounds. Mr. Theodore Cooper specified, in 1901, a range of from 54,000 pounds to 62,000 pounds for " soft " steel, and from 60,000 pounds to 68,000 pounds for " medium " steel.

At a meeting of the American Society for Testing Materials, held at Atlantic City last year, the question as to the desirability of specifying a single grade of open-hearth structural steel for bridges of ordinary span was discussed by some of the leading bridge designers and builders, and the matter very fully gone into, with the result that the general opinion of these engineers appears to have been that it was desirable to specify in future only one grade of steel for structural purposes, rivet steel, of course, not being included in this. The wisdom of this decision will appeal to English engineers who in their practice have always been satisfied with one grade of steel, having an ultimate tensile strength ranging from 27 tons to 32 tons per square inch. Why has it been the practice in America to specify two grades of steel? In order to answer this question it may be well, perhaps, to refer to the history of bridge-building in that country, as reviewed by Mr. C. C. Schneider, of the American Bridge Company, from the time that steel was first used as a structural material. When first adopted, steel was only used in structures of considerable magnitude, and then only in certain of the heaviest members, in order to reduce the dead load and the sizes, which at that time could, even in the largest bridge works, only be handled with difficulty.

Steel having a high ultimate strength and elastic limit was therefore specified, and the working stresses increased in proportion. As, however, more knowledge was gradually gained of the properties of steel, it was found that this very high steel was not a safe material to use in railroad bridges, for it was not adapted to withstand impact. Engineers therefore began to specify more ductility and a lower ultimate strength, and continued to lower their requirements for ultimate strength, as the price of steel decreased, until the ultimate strength had come down from over 100,000 pounds per square inch to from 62,000 pounds to 70,000 pounds, on what is now classed as "medium" steel.

Some twenty years ago, steel, as a structural material, was used only to a very moderate extent, and chiefly for large bridges or other special work; but gradually it came into extensive use, and railroad companies began to build small-span bridges and plate-girders of it; while for eye-bars it was almost exclusively used. Most of the rolling-mills that had up to that time manufactured wrought iron equipped themselves with steel furnaces, but continued for some time to manufacture both wrought iron and steel. The change from wrought iron to steel was, however, very rapid, until, a few years later, it was practically impossible to obtain wrought shapes, and engineers who would have preferred to use these were obliged to adopt steel instead. In consequence, they naturally specified a grade of steel as near to wrought iron as possible. In this way the present use of two grades of steel in America is accounted for; but as steel has now long passed the experimental stage, we are not surprised that there should be a movement on foot to simplify matters by specifying one grade only, for surely this should be an advantage both to the producer and to the consumer; to the former because he would be able to carry on his business on simpler and more systematic lines, and to the latter because he would be the gainer on account of the greater uniformity of the material which would result from only one grade of steel being manufactured.

Another argument in favor of the adoption of one grade of steel in America appears to be that at present a large percentage of the structural steel is made by the basic process, and it seems probable that this process will be the one of the future for ordinary structural steel. There is a prejudice against basic steel in certain quarters in this country, which prejudice we do not

consider is supported by facts; but in America no such feeling exists; basic steel, having an ultimate strength of from 58,000 pounds to 60,000 pounds per square inch, if properly manufactured, being looked upon as a highly satisfactory material for structural purposes. There is another argument also in favor of one-grade steel, which is, that by its adoption a more uniform practice all over the world may be established, and engineers who issue eccentric specifications will not receive much consideration from steel manufacturers.

Granting the advisability of adopting one grade of steel, the question has arisen among American engineers as to what is the proper grade of steel to use. Much discussion has taken place on the subject in the States, and most of the leading engineers there have expressed themselves on the subject, some arguing in favor of a continuation of the use of two grades of steel, while others (and they the majority) advocate strongly the adoption of only one grade, and that of the higher quality. After all, however, when the views of these men are examined and compared, there seems to be a wonderful unanimity. The prevailing impression left in the mind is that it is a case of Tweedledum and Tweedledee, and that the most suitable steel to adopt is one having an ultimate average tensile strength of about 60,000 pounds per square inch. The other properties of the material, such as the yield point, and the percentage of elongation, to be fixed to suit this range of tensile strength.

The preceding figures do not refer to rivet and pin steel, the former having to be soft and ductile, particularly for rivets put in during erection, and ranging between 50,000 pounds and 58,000 pounds ultimate tensile strength per square inch; while the pin steel must be quite hard, with a tensile strength between 75,000 pounds and 85,000 pounds per square inch.

The decision arrived at by the American Society for Testing Materials has been that a one-grade steel having an ultimate tensile strength of from 55,000 pounds to 65,000 pounds per square inch is, on the whole, very desirable; and this decision will no doubt bear fruit, to the advantage both of the manufacturer and the consumer. It has been clearly demonstrated that such steel is quite reliable, and may be used with advantage for all structural purposes; for it can stand more abuse than the best double-rolled wrought iron, and can be punched and sheared with

no greater injury than such treatment would inflict on the latter metal, if the thickness does not exceed five-eighths of an inch. We feel sure that American engineers are wise in having come to so important a decision. The situation may be very clearly summed up in the words of Mr. J. E. Greener, bridge engineer to the Baltimore and Ohio Railway: "Engineers should keep pace with the times. The so-called soft steels served their time after they had quieted the nerves of the conservatives. That time has passed, and at present there is no material difference in the working qualities of the soft and medium steels as usually furnished and accepted. Either grade can be rolled from the same billet."

IRON ORE IN SIGHT *

THE amount of iron ore "in sight," to use that abused but convenient expression, is a fairly determinable quantity, particularly in the Lake Superior districts, where the practice has been to explore far in advance of actual mining as a basis for a sale or lease of the property. So there is a statistical basis for the speculations as to the available supply of iron ore and for the prophecies as to an approaching scarcity of high-grade Bessemer ore. The chief consideration in the situation is the Lake Superior supply, since from that district in 1902 79 per cent of the iron ore production of the United States came and in 1903 an increasing proportion. The older eastern and southern districts do not hold any large ore reserves and the newer districts are as yet all uncertain or unavailable.

From the standpoint of the Lake Superior supply an interesting estimation as to the available iron ore of the whole country can therefore be drawn. Estimates made by the United States Geological Survey in 1902 of the amount of merchantable ore in sight, that is ore above 59 per cent in iron, give the ore reserve in the Mesabi district as 500,000,000 to 700,000,000 tons. The aggregate of ore in sight in all the other Lake Superior districts

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* "The Mining World," August 27, 1904.

is placed at 350,000,000 tons. Explorations since this estimate was made have not materially increased these reserves. It is fair, then, in the light of the present known facts about the iron ore supply in the Lake Superior districts to place the available reserve at 1,000,000,000 tons of 59 per cent ore. With this as a basis and the figures of annual consumption as a measure, the time of the exhaustion of these iron ore reserves can be estimated. The production of the Lake Superior mines in 1890-1-2 averaged about 8,000,000 tons, in 1893 it fell to 6,000,000. Since that time it has increased at about 2,500,000 tons a year. The production in 1902 was 27,869,000, and in 1903, 24,300,000 tons, to use round figures. Take this as indicating a present yearly demand for 25,000,000 tons, and allowing for no increase, the visible ore would be exhausted in 40 years. Allowing for an average annual increase of five per cent, which is a fair increase deduced from the years since 1899 and is within the estimated general increase of business for the country, not allowing for the yearly enlargement of the uses of iron in all lines, and it can be arithmetically computed that the available ore estimated will be all exhausted in 23 years.

On the other side of the question is the possibility and probability that iron ores below 59 per cent will be utilized in the near future. This will very largely increase the available supply, but how much cannot be estimated, as these "low-grade" ore bodies have not ordinarily been explored. Then there is a fair certainty that new ore bodies will be located within the districts now worked for ore. These new bodies cannot be very large nor can they effect the supply in any such manner as the finding of the Mesabi, for instance, did, but these undiscovered ore bodies are to be considered as a factor in the problem of ore supply. There is also a chance that new iron districts will be opened up in this region. The new Baraboo district in Wisconsin, though not up to predictions, has added perhaps 7,000,000 tons to the available ore. Explorations in Canada and on the western extension of the Mesabi give some promise of new sources of supply. The recent discovery of a new iron district in Aitkin and Crow Wing counties in Minnesota may be of importance. These new districts, however, have not since the discovery of the Mesabi in 1893 come up to the expectations. Notably has the Michipicoten district in Ontario failed to realize the hopes of its discoverers

The other iron ore deposits in eastern Ontario are uncertain as to extent also.

So we have a possibility that within a quarter of a century the Lake Superior mines will be unable to meet the demands for a high-grade ore.

The western deposits are a factor in the future, but most of these are at a disadvantage as to transportation. In fact, they are all cut off from the eastern consumption by the necessarily high freight costs. The consumption of iron in the western furnaces may supply the local demands and relieve the demand on eastern furnaces to this extent. It is generally believed that these western deposits are not generally so extensive as claimed and further that with depth the ore will become valueless by reason of the increasing sulphur content from the sulphides from which most of these ore bodies, except perhaps those in Wyoming, are derived. The iron ore in Mexico may be an important factor at no distant date. The deposits available to the Pacific Ocean are now being secured by American capital as a supply for proposed furnaces at American Pacific ports and an iron property near Vera Cruz is preparing to ship ore to the Atlantic ports to be consumed with the relatively small amount of Cuban ore now imported for this market.

But the fact is that but for the bountiful supply of cheaply mined and transported ore from the Lake Superior districts the wonderful progress of the country in industrial lines would not have been possible and it will be necessary to figure on the day when the Lake Superior supply will be exhausted or be of a lower grade except as to reserves held by special interests.

THE IRON AND STEEL INDUSTRIES OF THE WORLD*

A Study of the Statistics of Manufacture, Exports, and Imports in Connection with the Industrial Position of Great Britain

By WILLIAM POLLARD DIGBY
Society of Arts

WHATEVER may be the outcome of the present agitation in Great Britain with regard to the much discussed fiscal question, there is no doubt that it has been, and will doubtless continue to be the cause of the study of a number of most important elements which go to make up the manufactures and commerce of the Empire. Among such investigations we may note an important paper examining the statistics of the iron and steel industries of the world, recently presented by Mr. William Pollard Digby before the Society of Arts, and published in the "Journal" of the society.

Mr. Digby examines the subject from three separate points: that of the supplies of ore and the production of pig iron in the United Kingdom, as compared with Germany and with the United States; that of the relations of the import and export trade of Great Britain to the external trade of other countries; and that of the margin of profit of the iron industries reckoned on the external trade alone of the leading iron-producing countries.

"A complete survey of so vast an undertaking as the British iron trade, with its many ramifications, its complex questions, might well appal a Royal Commission, while an extension of the survey to the dissection of the exact situation in regard to every branch of the iron and steel industries of the United States and Germany would occupy a special International Commission for an indefinite period.

"The difficulty likewise hinges upon the question of internal consumption, of what proportion the home market bears in each case to the country's export trade, and as to how far the imports from other countries affect the home market. The relation of the import and export trades to each other is easily defined, and the chief sections of the import and export trade receive separate enumeration in the various Government returns. While it is possible to define the value, say, of steel rails, respect-

* "The Engineering Magazine," July, 1904.

ively imported and exported from the United Kingdom, we do not know the total production of the value of steel rails used in any year by the different railway companies and tramway undertakings within the kingdom. Again, it is possible to give the value in any year of the locomotives sent to foreign countries and to our own Colonies, and it is not difficult to enumerate the sporadic dumpings of locomotives into England on those occasions when lack of foresight had allowed the number of engines under construction to fall below immediate requirements, so that occasional purchases from America resulted. We can, in this latter case, go a step further and give the number of locomotives included in the rolling stock for any one year. But we cannot give the amount of the expenditure in any year on new locomotives either for our railways or for the rough lines laid by contractors for their dock, or reservoir, or railway, constructional work.

"Similarly, if we regard shipping, while returns have of recent years been published giving the values of our sales of new ships built for foreign countries, we have no return of the value of the yearly additions to our mercantile marine, or of the value of the plates, rivets, or stern-frames which, forming the raw material for the shipyard, are nevertheless the finished product of the steel merchant. We are also without returns as to the value of the iron and steel supplied to the ship's engine builders wherein 'the purring dyamos,' the towering five-crank reciprocating engines, the compact turbines, the belauded Scotch and belittled Belleville boilers, find their raw material.

"Turning to the textile of electric cable factories of Lancashire of the paper mills of Thames valley, no returns tell of the proportion of foreign machinery therein installed or of the extent to which the manufacturers of their myriad engines, boilers, looms, brading machines, potchers, shafting, or pulleys have indented directly on foreign or on British machine makers, or have purchased high-class machinery, itself in part made from raw iron or raw steel produced, perchance, in a foreign country."

Taking up first the question of the production of iron ore and pig iron, the statistics of Great Britain, Germany, and the United States are shown by curves covering the past thirty years. Broadly these show a gradual fall in British production of ore as against an increasing British consumption. Both Germany

and the United States have been developing their own local deposits, although both England and Germany are obliged to look abroad for the raw material for their furnaces. It is this question of the necessity of importing iron ore which has, in the minds of many, placed Great Britain at a great disadvantage, but Mr. Digby calls attention to the fact that the inflow of ore, essential to the existence of British iron furnaces, supplies also income on British investments.

"Ore beds in northern Spain have been purchased, railways built, and machinery supplied. Steamship services have been organized, blast-furnaces erected on the sea-board, so that in some cases the ore is carried with only two handlings from the ship's hold to the furnace mouth. Those who talk loudly of the extinction of the iron industry have not recked of the manner in which the iron industry has called, not in vain, on the country's capital to provide other sources of raw material."

In this respect the position of England is not unlike that of the Pittsburg district in the United States: the supply of ore brought by the lake steamers having developed the iron-making industry on the shores of the Great Lakes. There is this difference, however, that in the United States the supply of ore may and does lie in other states of the Union, but not without the boundaries of the nation, or in another country.

Taking up the question of the export and import trade of the several countries, some interesting features are brought out. These also are plotted in diagrams, showing that, while British export trade has suffered fluctuations, it has, on the whole, exhibited a steady rise, and furthermore, has shown a corresponding proportion of profit. It is with the margin of profit between exports and imports that Mr. Digby concerns himself, and in this respect he takes an interesting view of the question, computing the relative value of the profit measured in food. For this purpose he makes use of Sauerbeck's index values for food for the corresponding periods. Upon this basis it appears that the maximum of profit was not in the early seventies, the era which has been so often cited as the zenith of free trade prosperity, but between 1888 and 1892. It may be advanced that while the coefficient of food profit has advanced the population of the country has advanced at an even greater rate. This, however, is considered by taking the profits per head of population, which has some interesting features.

Mr. Digby takes the period from 1868 to 1902, divided into quinquennial periods, and from his figures it appears that during that period the profits per head of population have fallen off to about one-half that which obtained at the beginning. At the same time the profit margin per head of population in the United Kingdom still stands at about threefold that recorded for either United States or Germany. These latter countries, however, show an increasing rate, the United States a rapid one, Germany more slowly.

A strong plea is made by Mr. Digby for more complete statistics of internal trade.

"Whether our studies of industrial economics will on one hand continue to be as full and as complete as the wit of man and the Board of Trade returns can make them, or on the other hand be limited to surmises based on the condition of the external trade (simply and solely because we have no records of the quantities and values of our manufactures which are internally consumed) rests with the manufacturers of this country. Any person can prate of exports and imports, but who can speak even in regard to iron, of the employment given to thousands of artisans making looms for Lancashire, locomotives and rails for our railways, dynamos and arc lamps for our street lighting, steel girders and angle iron for our large buildings? Or, again, as regards the value of the shipping added each year to our mercantile marine; while it would not pass the wit of Dr. Ginsburg to estimate the capitalized value of the shipping on Lloyd's Register, even he might fight shy of estimating the apportionment of the expenditure of a single year's increase among the many industries whose concerted efforts have fed the ship builder. Yet large quantities of our food imports are paid for by new ships made to foreign order, other quantities of food are paid for by old ships sold for a few more years of life or to be broken up, while still other quantities of the imports which enter the country are the earnings of ships carrying the red ensign and launched in the preceding year.

"A great volume of our iron must surely go into what, for varying reasons, are investments which are directly or indirectly remunerative, railways, shipping, locomotives, lathes, looms, or other machinery; even the hammer and cold chisel are not unproductive directions either for home manufactures or imports.

"'Among the blind, the one-eyed is King.' What shall

we say of John Bull, who is not even equipped with half his powers of vision when considering his own entire commerce? External commerce is clearly displayed in export and import returns. Internal commerce is practically shut off from his vision. Its fruits, so far as percentage of pauperism or saving banks returns are concerned, can be gauged any day. But the full extent of the effects of 'dumping' can only be truly known when manufacturers will consent to a dissection of the statistics, not only of the trade of manufacturer A whose finished article is threatened by foreign competition, but also by a dissection of the trade of manufacturer B whose raw material is often the finished product of manufacturer A.

"At a time when ill-digested statistics are thrown to and fro in argument, a plea for more statistics sounds impertinent. Yet some measure of the relation of imports not alone to exports, but to home consumption also, is surely necessary before we talk of doomed industries. Will none cease from a strife of the rival panaceas — protection, altered business methods, temperance, retaliation, education, free labor, bounties, and so forth (good though some of these may be) and unite to obtain the true figures of internal trade and its relation to exports and imports? For, only when these have been obtained are the component parts available with which alone it is possible to paint the only veracious picture of the nation's true condition."

ABSTRACTS *

(From Recent Articles of Interest to the Iron and Steel Metallurgist)

The Hartman-Kennedy Fire Brick Stove. John M. Hartman and John S. Kennedy. "The Iron Age," August 8, 1904. 500 w., illustrated. — This article describes a plant consisting of three brick stoves and an equalizer recently designed by the authors and erected at the Musconetcong Iron Works at Stanhope, N. J.

In the construction of the stoves the following improvements were designed. Each stove is provided with an external combustion chamber, which is a horizontal cylinder twelve feet long by five feet diameter in the clear. The gas is admitted to this combustion chamber by a 21-inch opening, and after its ignition passes into the stove by two 30-inch necks. The object of these external chambers is to make perfect combustion of the gases before passing them into the stoves, to provide for the deposition of flue dust where it can readily be blown out and where any fused or clinkered material can be easily reached and removed.

The stoves are of the Hartman two-pass type, provided with a heavy 18-inch partition wall in the first regenerator pass. The stoves are 19 feet in diameter by 76 feet to top of dome. The three stoves contain 106,500 square feet of heating surface. The openings in the first regenerator pass are 9×9

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* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

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inches, with nine-inch walls; and in the second pass 5×5 inches, with $2\frac{1}{2}$-inch walls. These stoves will heat 22,000 cubic feet of air per minute and with the equalizer will give an average uniform temperature of 1,200 degrees.

The equalizer, which is the first to be erected in this country, is 12 feet 6 inches diameter by 19 feet 9 inches to top of dome. There are two passes for the hot blast, and the regenerators are filled with 2×2-inch passages with $1\frac{1}{2}$-inch walls. **No. 212. B.**

The Constitution of the Copper Zinc Alloys. E. S. Shepherd. "The Journal of Physical Chemistry," June, 1904. 5,600 w., 2 diagrams and 46 photomicrographs. — The author describes the results of an extensive investigation which he conducted at Cornell University under the direction of Professor W. D. Bancroft. The expenses incurred in the research were covered by a grant from the Carnegie Institution. The author records the existence of a quadruple point in the freezing-point curve of copper-zinc alloys which had escaped the notice of previous investigators. The freezing-point curve consists of six branches which imply the possible existence of six different solid phases, one in equilibrium with each branch of the curve. These six phases the author designates as α, β, γ, δ, ϵ and η, and their limiting concentrations were determined. The microsctructure of alloys containing various proportions of copper and zinc is carefully described and illustrated, the nature of the constituents being inferred from the position which these alloys occupy in the freezing-point curve. The color of copper zinc alloys is also considered. **No. 213. D.**

The Manufacture of Iron by Electro-Metallurgical Processes. Adolphe Minet. "The Engineering Magazine," August, 1904. 7,000 w., illustrated. — A comprehensive paper describing the most important processes used for the extraction of iron by electro-metallurgical methods. The author concludes as follows:

"As may be judged from the present study, the efforts made by electro-metallurgists have already been considerable, and their enterprise deserves to be taken into consideration seriously; they have also to their credit the easy and eco-

nomical production of the whole series of alloys of iron or steel with silicon, manganese, chromium, tungsten, titanium, and nickel, which require from metallurgists a consumption of coal double and sometimes triple that required in the metallurgy of iron.

"Some of their plants are in full activity; among others those, for instance, of the Société Electro-Métallurgique de Frages, in France (Frages-Héroult process), those at La Praz (Savoy), at Frages (Isère) and in Sweden where they are competing with the Kjellin process. I may add that they are already furnishing to the industries by hundreds of tons irons and steels of all kinds and iron and steel alloys of every nature." **No. 214. B.**

The Electro Metallurgy of Iron and Steel. A. F. Schneider. "Mining Magazine," August, 1904. 2,500 w., illustrated. — The author describes some of the processes in use for the production of iron and steel by electro-metallurgical means. **No. 215. B.**

Electro-Chemical and Electro-Metallurgical Industries. Part IV. Iron and Steel, Lead, Nickel, Tin and Zinc. J. B. C. Kershaw. "Technics," August, 1904. 4,000 w., illustrated. — The author describes some of the most important electro-metallurgical processes for the production of iron and steel. **No. 216. B.**

"Transactions of the American Foundrymen's Association." — The last issue comprises the report of the Convention at Indianapolis June 7th, 8th and 9th, 1904. It contains the following articles of interest:

"Scrap Iron Specifications." W. G. Scott.

"Molding Machines and Their Uses." E. H. Mumford.

"Pig Iron Warrant System and the Foundry." G. H. Hull.

"Molding Machines of To-day." H. M. Ramp.

"Sulphur in Pig Iron." R. S. MacPherran.

"By-Product Foundry Coke." C. Schwerin.

"Shot Iron." James Boyle.

"Cupola Fan Practice." W. H. Carrier.

"Fan Blowers for Cupola Work." G. W. Sangster.

No. 217.

"**A Review of the Cast-Iron Wheel Situation.**" C. W. Gennet, Jr. "The Railroad Gazette," August 12, 1904. 2,000 w. — An interesting article descriptive of the development of cast-iron wheels, causes of failures, etc. The author concludes as follows:

"With these different forms available, wheel makers and users are struggling for results, and how their efforts are best succeeding must be left for time to tell. The great question is whether or not experience will demonstrate that the cast-iron wheel must give way to steel, and the matter of expense will have relatively slight influence on the decision, if other requirements demand the change." **No. 218. B.**

Power Installation at the Isle of Elba for the Utilization of Blast-Furnace Gas. Emile Guarini. "Power," August, 1904. 600 w., illustrated. — The author describes an electric installation recently made by the Westinghouse Company for the Société Elba of Porto Ferraio, Isle of Elba, for the production of motive power, by means of dynamos and gas engines supplied with blast-furnace gas. The two blast-furnaces have each a capacity of 200 tons per day. A steam engine and two Cockerill gas-operated blowing engines furnish the blast for the furnaces. The central station contains three groups composed of a Westinghouse generator of 100 kilowatts capacity at 290 volts, belt connected to a Cockerill gas engine of 200 horse-power running at 190 revolutions per minute. The gas from the furnace is first passed through a Theisen purifier. **No. 219. B.**

Accuracy in Testing Materials. W. C. Popplewell. "The Engineering Review," August, 1904. 5,000 w., illustrated. — The author discusses at length the question of accuracy in the mechanical testing of metals in the following order: The degree of accuracy necessary, accuracy in determining stresses, accuracy of testing machines, calibrating testing machines, examples of calibration tests, precision of testing machines, accuracy in determining the area of cross-section, reporting yield-point and maximum stress, reduction in area and elongation. **No. 220. B.**

Blast-Furnaces in the Ural. Abstract from a paper by J. Bicheroux in the "Revue Universelle des Mines" for February, 1904. "Iron and Steel Trades Journal," August 20, 1904. 1,400 w.

As a rule the smelting plants are of small size, and of primitive equipment. They comprise one or two furnaces, 40 to 56 feet high with three tuyères, tapering in profile with thick masonry supporting pillars, the whole covered in a tower of brick, supporting the platform of the furnace top. This is open, and an inclined plane of gentle slope leads to it, the charge being drawn up by horses, in wagons made of wood for the ore, and of wicker for the charcoal. The charging is done by shovels. The gas is used to heat the blast in contrivances that vary widely. The blast is supplied generally by a piston-blower of very small power, driven by a water wheel in summer and in winter by a steam engine, often very large, joined to the same shaft and receiving steam from a battery of boilers that are fired with wood. The apparatus is usually ill-planned, and turns out a daily production of 12 to 15 tons per furnace, with an excessive amount of labor. **No. 221. B.**

"The Foundry." — The September issue of "The Foundry" contains the following articles of interest:

"Foundry of Stilwell-Bierce and Smith-Vaile Co., Dayton, Ohio."

"Warping of Castings." T. Mack.

"Some Examples of Irregular Distribution of Sulphur in Pig Iron." J. J. Porter.

"Molding in Cores." H. J. M'Caslin.

"Does Iron Expand?" H. Sayers.

"The Pattern Shop and the Foundry." H. L. Post.

"Economy in Melting." J. P. Pero.

No. 222. A.

Notes on Metallography. William Campbell. "School of Mines Quarterly," July, 1904. 8,000 w., illustrated. — The author describes the technology of metallography, including the preparation of samples, the microscope and accessories, the illumination, the photography of the samples, etc. **No. 223. C.**

Alloys Used for Steel Making. Dr. J. Ohly. "Mines and Minerals." August, 1904. 3,000 w. — The first two instalments of this article were published in "Mines and Minerals" for October and December, 1903, and reviewed in our abstract No. 67 (February, 1904). In this concluding instalment the author describes Ferro-titanium, ferro-vanadium, ferro-boron, ferro-manganese, ferro-uranium, ferro-aluminium, ferro-sodium, ferro-silicon and copper-silicon. **No. 224. A.**

Conduit System of Handling Blast-Furnace Stock. "The Iron Trade Review," August 18, 1904. 1,800 w., illustrated. — A full description of a conduit system for handling blast-furnace stock introduced at a number of southern furnaces. The system has been patented by A. H. Woodward and developed by Walter Kennedy. **No. 225. A.**

Loss in Malleable Foundries. R. F. Flintermann. A paper prepared for the Indianapolis meeting of the American Foundrymen's Association. "The Iron Trade Review," August 25, 1904. 2,400 w. — The author reports the results of tests recently made at the McCormick works of the International Harvester Co. to determine the amount of loss and shrinkage in malleable work. The author concludes that in their practice the loss should not exceed five per cent. **No. 226. A.**

High Temperatures Measurements. S. H. Stupakoff. "The Iron Trade Review," July 14, August 4 and 25. 3,500 w. — A critical review of the various methods employed for determining high temperatures with special references to iron and steel furnaces. **No. 227. A, each.**

Modern Methods of Steel Casting. J. C. Horner. "Technics," July and August, 1904. 5,000 w., illustrated. **No. 228. B, each.**

EDITORIAL COMMENT

John August Brinell

It is with a great deal of pleasure that we publish as a frontispiece to this issue an engraving from a recent photograph of the distinguished metallurgist, John August Brinell. Few metallurgists have done so much towards the advancement of the metallurgy of steel as Mr. Brinell, and he richly deserves his world-wide reputation as a remarkably able investigator and successful steel works manager. For his most important experiments dealing with the heat treatment and testing of steel he is entitled to the gratitude of all steel metallurgists.

John August Brinell was born in Sweden, June 19, 1849. In 1871 he graduated from the Technical School at Borås. After four years' practice as draughtsman, he entered in 1875, as general superintendent, the Lesjöfors Iron and Steel Works, at that time directed by the late Gustaf Ekman, the well-known inventor of the gas-welding furnace which bears his name.

In 1882 Mr. Brinell became the chief engineer of the Fagersta Iron and Steel Works, and since that time he has been connected with that company until the beginning of this year, when he assumed the duties of chief engineer at Jernkontoret.

Among his most important writings may be mentioned "Changes in Texture on Heating and on Cooling," a memoir which is now classical, and "A New Method for Determining Hardness and Some Applications for the Same," in which the author describes his well-known ball test for the physical testing of metals.

The following distinctions of which Mr. Brinell has been the recipient show how highly the value of his work has been appreciated: In 1896 he was created Knight of the Royal Order of the Wasa, in 1899 Knight of the Royal Order of the Polar Star and in 1900 Knight of the Legion of Honor. In the same year the Swedish Society of Technologists awarded him the Polhem medal for a paper on a new method for the determination of

hardness, and from the jury of the Paris Exhibition he received the "Grand Prix" for his experiments on iron and steel shown in connection with the Fagersta Co.'s exhibition in the Swedish court. In 1903 the Swedish Academy of Sciences awarded the Ainberg prize to Mr. Brinell.

The Value of Science in Steel Working

In a paper by a well-known steel manufacturer presented to the International Engineering Congress recently held in St. Louis, the author apparently questions the value of "science applied to steel making," his attack being more especially directed to the value of the microscope and pyrometer. Were such views expressed by a person of indifferent professional standing they could be summarily dismissed on the ground of irresponsibility and, therefore, of carrying with them but little weight. Coming, however, as they do, from a man who was a pioneer in the manufacture of crucible steel in the United States, and who has attained a prominent position in his profession, they are entitled to recognition. When the author entered into his successful career, the rule-of-thumb methods reigned supreme and most of the progress he witnessed, and, indeed, to which he contributed, was accomplished by empirical methods. And let it be proclaimed, to the full credit of these methods, that the advance made through their instrumentality has been very great indeed. But they have now yielded about all they were able to contribute to the art; they are well nigh exhausted, and for the last decade or two, the progress recorded has been due to the intelligent application of the results of scientific methods, including the use of the pyrometer and microscope. The attitude of the author in this matter was also the attitude of those so-called "practical men" who some thirty years ago refused admittance to the chemist, on the ground, following the author's argument, "that nature had supplied" the best analytical balance "in the trained eye." To-day these same men are reaping the rich harvest sown by the chemist, but many have failed to appreciate the teaching which it implies, for it is still their present attitude towards pyrometry, metallography and in general towards all scientific methods which make for progress in all arts, and which fortunately cannot be seriously held back by their lack of appreciation.

Notwithstanding the author's opinion that "any extensive

use of the microscope and pyrometer in the mills is doubtful," and while these instruments may not be employed in his works, thousands of pyrometers and hundreds of microscopes are in use daily by manufacturers, workers and consumers of steel, and their number must increase because the course of progress cannot be stayed. The author offers, as supporting his view against the usefulness of the microscope, the fact that the structure revealed is that of "various spots of the size of a pin head." Quite so, and similarly the chemist uses only a few grams of metal to determine the composition of ten, twenty, fifty tons of steel. Do we deny on that account the value of his work? The author also tells us that there may be a "difference of 1,000° in the temperature of different parts of the same bar," and asks "at what part of such a bar shall a pyrometer be applied." If this is an instance of the results of heat treatment conducted by rule-of-thumb methods, it presents a striking evidence of the urgent need of the application of pyrometers. The author sums up his arraignment by the following statement: "Nature has supplied the best pyrometer and microscope combined, in the trained eye, governed by good sense and sound judgment, *and it is doubtful if, for good work, these natural faculties will ever be improved upon by any instruments of man's devising.*" The italics are ours. Such a statement hardly demands refutation. Let it be nailed in a conspicuous place; it carries with it its own condemnation.

IRON AND STEEL METALLURGICAL NOTES

Iron Making in the Lake Superior Region. — The question of the best situation for blast-furnaces, which has been often discussed from different points of view, has, for the most part, found a practical solution in this country by the placing of the furnaces within convenient distance of the fuel supply. In other words, it has been found more economical to carry the ore to the fuel than the fuel to the ore. Many attempts have been made in the past to establish blast-furnaces in the Lake Superior country to carry out the opposite view, but, with very few exceptions, they have not been successful; and those exceptions have been mainly charcoal furnaces of moderate size, the fuel for which was derived from the forests of the Upper Peninsula of Michigan. There was reason for this. Coke, which is the staple blast-furnace fuel of this country, will not stand the frequent handling necessary to forward it to the Lake Superior country by rail and lake, while the all-rail freight charges are too high to permit of its use in smelting with a profit.

A new departure, however, has been made by the Zenith Furnace Company, of Duluth, which has just completed an extensive plant at that city, and which proposes to run a blast-furnace there, believing that a profit can be secured in the manufacture of iron from Mesabi ores at that point. The plant, which is described fully in another column, differs in some important respects from all the previous undertakings of the kind. The company will not attempt to transport coke from Pennsylvania to Minnesota, but will carry the raw coal and convert it into coke in the immediate neighborhood of its furnace, relying upon the profits to be derived from the various by-products to pay in large part, if not altogether, the expenses of the transportation. Among the most important of these by-products will be the gas from the retort coke ovens, for the sale of which a contract has been made with the neighboring cities of Duluth and Superior.

The plans appear to have been well worked out, and the plant well designed for the purpose. It is certainly a most interesting experiment, not only on account of the locality, but because it is one of the first blast-furnace plants in this country where the by-products are to play an important part. There are already a few furnace plants which make their own coke, but that is not at present the general practice, the custom being to buy coke from the ovens and transport it to the point where it is to be used in that form. In more than one respect, therefore, the Zenith Furnace Company deserves credit for its enterprise, and in some points it may serve as an example to other companies. The outcome of the experiment will be watched with interest, and we certainly wish the new plant all success. — "Engineering and Mining Journal," August 11, 1904.

New Method of Manufacturing Steel. — It is reported that successful experiments have just been made by the Iron, Steel and Metals Manufacturing Company at Melbourne, Victoria, for the purpose of proving the value of certain patent rights for the direct production of wrought iron and steel without first producing pig iron. Only a rough idea of the process may at present be had, though trial runs with New Zealand magnetic iron sand are now being made on a somewhat larger scale than hitherto. The sand is first separated from its gangue by electro-magnetic separators, this treatment leaving a pure magnetic iron oxide. The sand is then fed from a bin into the furnace, which is entirely novel in its features, being chiefly mechanical and automatic in its operation.

The ore drops from the bin into a slowly revolving cylinder placed at such an angle that the ore travels forward continuously in it. As it does so it is heated to a dull red by the waste gases from subsequent operations. From this cylinder the ore drops into a second revolving cylinder, where the fine particles are subjected to the action of reducing gases which reduce the magnetic oxide of iron to the metallic form, at the same time permitting the particles to retain their individuality. From this second cylinder the reduced ore drops into a smelting bath at the bottom of the revolving cylinders, and the molten steel or malleable iron, as the case may be, is tapped

from this whenever that operation is necessary. It will thus be realized that the process is one of great simplicity and yet of much ingenuity. Not the least interesting part of it is the use of fuel oil for heating purposes. This is employed to secure concentration of heat and direct application in the furnace work. It is found that the fuel oil possesses many advantages over producer gas as used in existing smelting practice. The work done so far has demonstrated that not only is oil a cheap fuel, quite irrespective of the capital outlay that would be required if it was decided to utilize producer gas, but it is so thoroughly under control as to insure the best service.

The temperature at which iron ore melts is given variously at from 1,500° to 2,000° C., according to its purity.

The accurate gaging of temperature in the furnaces plays a very important part in the company's work, and accordingly an installation of thermo-electric thermometers has been made at the company's works. The apparatus consists of a "couple" consisting of a platinum-iridium junction inclosed in a metal tube fully three feet long, which is placed in the center of the furnace, and the temperature is then recorded on the dial of a special form of voltmeter, each division on which represents 25° C. This voltmeter reads up to 1,600° and is placed at any convenient distance from the furnaces. The various thermometers are connected with a switchboard, which is again connected with the "couples" or tubes in the furnace. In the installation under notice four "couples" will be used, inserted in different parts of the furnace, and separately connected with the board, so that the reading of any thermometer can be taken and any discrepancy in the heat of different points of the furnace can be quickly remedied. It is interesting to notice that the voltmeter is so extremely sensitive that variations of heat down to 0.5° were easily noticeable in the trial test. The greatest temperature recorded was 1,300° C., equal to 2,340° F. — John P. Bray, Consul-General.

The Morrison-Kennedy Chimney Valve. — An innovation in the method of chimney valve connection for hot-blast stoves, introduced at several leading blast-furnace plants about two years ago, has resulted in economies that have brought it unceasingly into use. Reference is made to the Morrison and

Kennedy chimney valve, which is manufactured by the patentees, Thomas Morrison, of the Carnegie Steel Co., and Hugh Kennedy, of the Buffalo & Susquehanna Iron Co., Buffalo. The familiar chimney valves have a stack connection on the hot-blast stoves, the valve having a water-cooled seat in the bottom of the casing, with a large poppet valve raised and lowered on the seat. When the valve is let down the blast pressure is on top of the seat which, on account of the height of the valve and the distance to the stuffing box on top of the casing, is hard to make tight. There results the common leaking of the blast around the valve into the chimney flue, and fine Mesabi ore frequently cuts openings so that the blast from the engines is blown into the flue and out at the top of the chimney instead of going to the furnace. Instances have been known in which nearly ten per cent more iron was produced after leaks at chimney valves had been stopped.

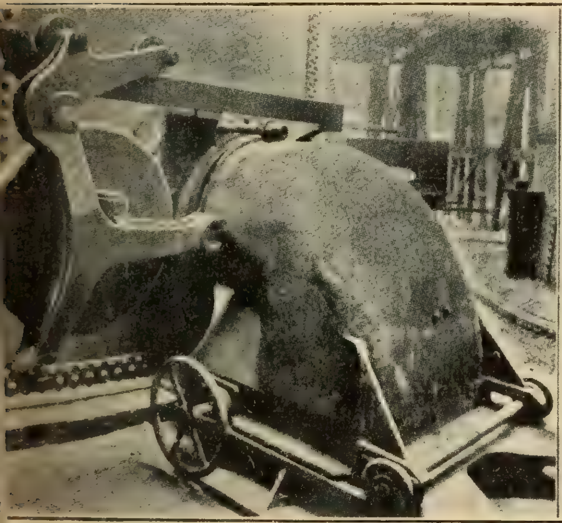


Fig. 1. Morrison-Kennedy Valve Connected Up Between Stove and Flue.

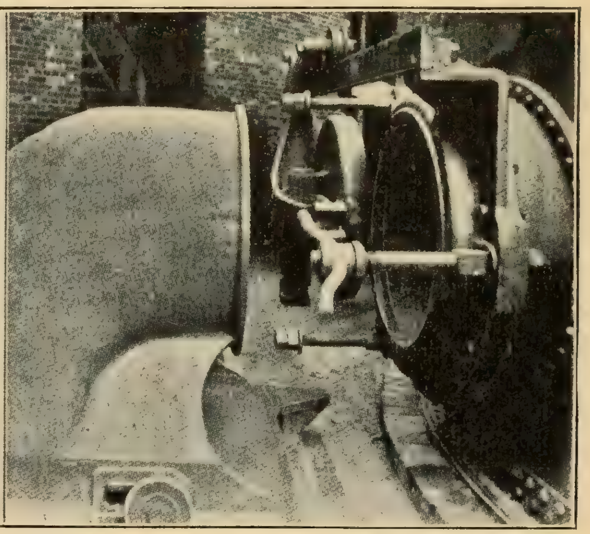


Fig. 2. Valve Disconnected from Stove Just Before Closing Opening to Put Blast on Stove.

Two types of the Morrison-Kennedy valve are illustrated. The larger valve, of which but one to a stove is used, is shown in Figs. 1 and 2. These views are from photographs taken at the Buffalo & Susquehanna Iron Co.'s furnaces at Buffalo, where eight stoves are equipped with the new valve. Fig. 1 shows the valve connected up between the stove and the chimney flue as it is when the gas is burning on the stove. Fig. 2

shows the valve disconnected from the stove just before closing the opening to put the blast on the stove. The Morrison-Kennedy valve when disconnected from the stove slides back. Bottom plates cover the opening to the flue and the door is pushed across the opening and bolted tightly to the face of the valve on the stove. This makes a complete disconnection of the stove and the chimney flue and leakage can be detected quickly by the furnacemen and remedied, whereas with the old-style valve leakage may be constant without being noticed.

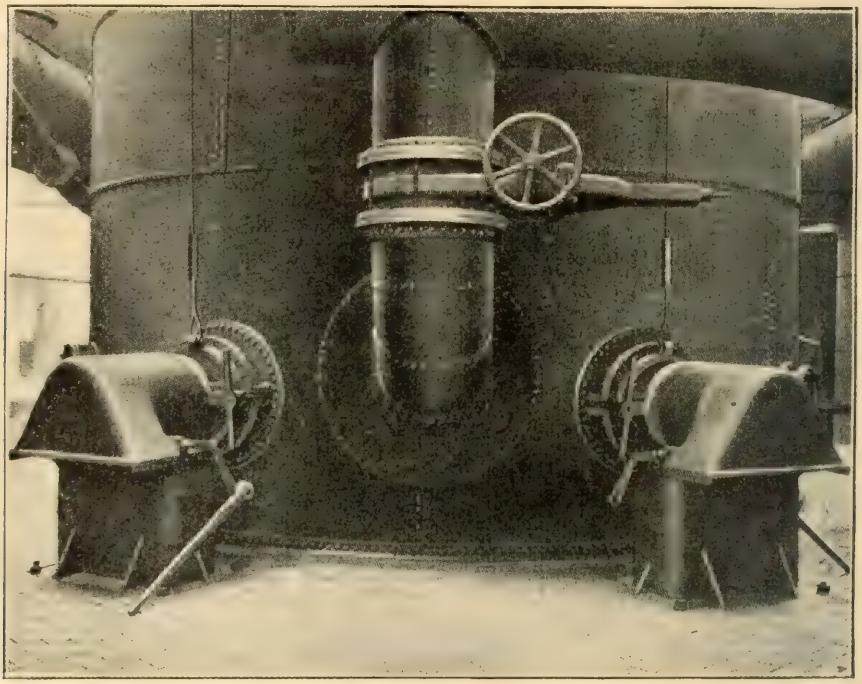


Fig. 3. Smaller Type of Morrison-Kennedy Chimney Valves. Opening Closed and Blast on Stove.

Fig. 3 illustrates the smaller Morrison and Kennedy valve connection, of which two are used for each stove. The absence of grooves or pockets in which flue dust may collect is one of the features to which attention is called. Very little room is occupied and the use of water is dispensed with. The small amount of wear possible is also a consideration, but the chief end accomplished, and that on which this form of valve connection has made noteworthy records, is in the complete stoppage of leaks, making available for use at the furnace almost the entire efficiency of the blowing engines. — "The Iron Trade Review," July 7, 1904.

Continuous Open-Hearth Process. — In a recent number of "Stahl und Eisen," Dr. Surzycki describes an open-hearth furnace that has been working satisfactorily since September, 1902, at the works of B. Hantke, at Czenstocha. In this furnace, which is of 30-ton capacity, two tap-holes situated one over the other, but not in line, lead into a double spout by which the whole or any part of the contents of the furnace are easily tapped at any time. The furnace is charged with cold scrap to which, when melted, molten pig iron from a blast-furnace or a mixer is poured in. When the bath is quiet, iron ore and mill-scale are added, and a further amount of pig iron. The charging lasts until the furnace is quite filled. The charge is dephosphorized by adding lime, and when decarbonization has gone far enough the furnace is tapped. The deoxidation of the steel is carried out by adding wood carbon and ferro-manganese in a ladle during the tapping of the charge. After tapping, the upper tap-hole of the furnace is closed and the furnace repaired. A calculated amount of ore and roll scale and a proportionate amount of pig iron is then run in. The practice is carried out uninterruptedly for one or two weeks. If, from any cause, the remainder of the furnace contents must be cast, it is easily done by opening the lower tap-hole. The method, while based on the Talbot process, has the advantage that it may be worked in an ordinary fixed furnace, if not too small. — "Journal of Franklin Institute."

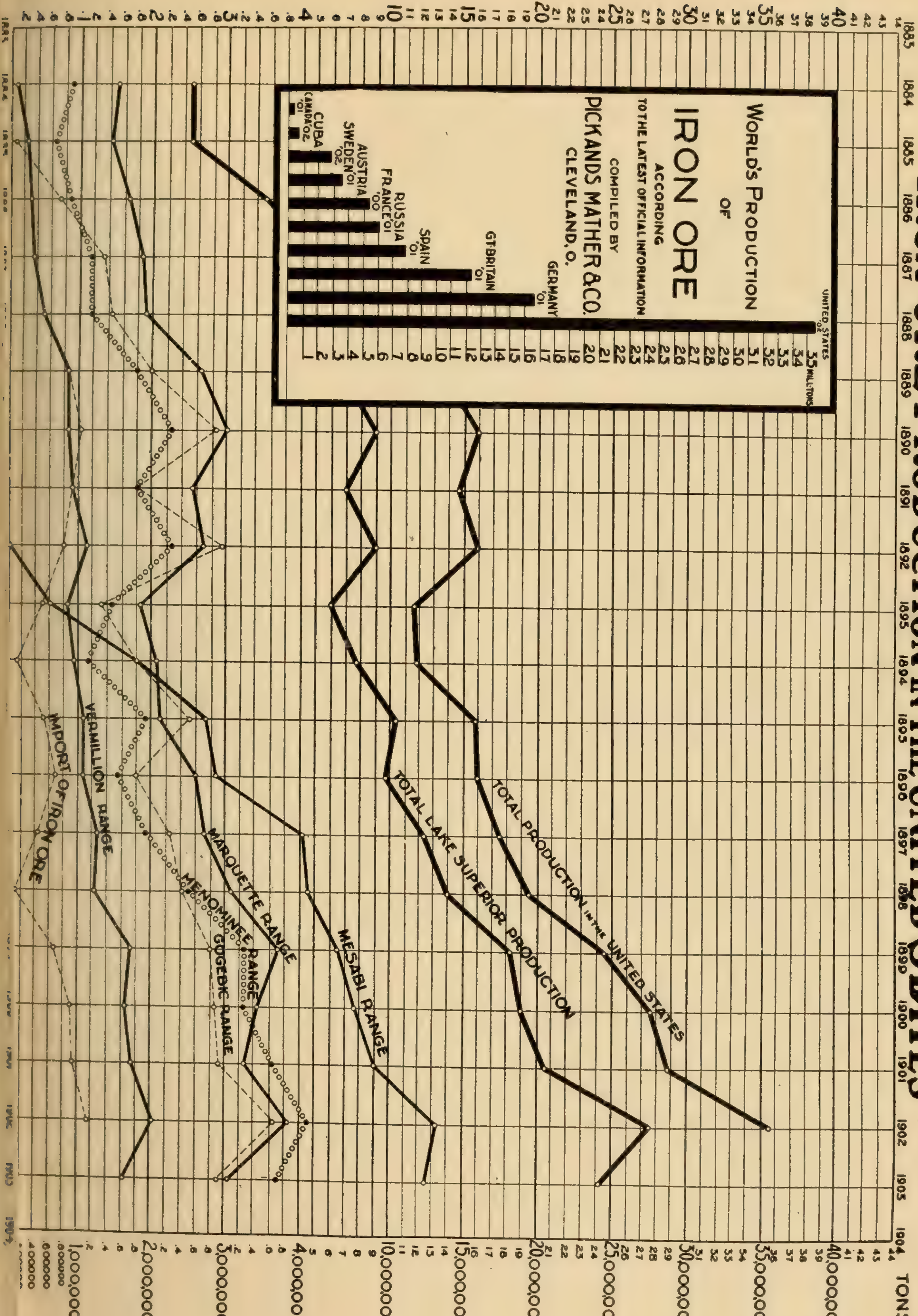
Behavior of Zinc in the Iron Blast-Furnace. — Many iron ores in Virginia contain 0.1 to 0.6 per cent zinc, which causes considerable trouble in the furnace operation by forming deposits consisting chiefly of zinc oxide. These deposits form just above the stock line, in the downcomer, flues, and hot-blast stoves. The furnace lining also absorbs zinc, in largest amount at zone. These phenomena were described by S. Porter in the "Iron Age," March 24, 1904. In six months a furnace used 28,746 tons of ore containing 202.8 tons of zinc, of which the following was accounted for: In flue deposits, 36.5 tons; in downcomer deposits, 18.2; in furnace deposits, 16.6; in flue dust, 18.3; in dust-catcher dust, 16.0; absorbed in hearth lining elsewhere, 10.0; lost in gas wasted at top, 18.6; total, 141.3; unaccounted for is represented by dust in stoves,

boilers, chimneys, and carried away in chimney gases. In no case did the slag assay higher than 0.05 per cent zinc. — "The Engineering and Mining Journal," August 18, 1904.

Iron Ore Production in the United States. — The accompanying cut showing the ore production of the United States and the Lake Superior iron ranges by years will be found very interesting to the mining contingent of this region. By reference to it one may read at a glance the fluctuations of the industry from year to year for the past two decades. One of the most interesting facts disclosed by the map is that the iron ore production of the United States was about 35,500,000 tons in 1902, and the Lake Superior region furnished about 27,500,000 tons of it. The sharp decline in the production of the great iron ranges from 1902 to 1903 is shown. The most remarkable thing is the sharp ascent of the line indicating the development of the iron mining industry on the Mesabi range. The upright lines showing the comparative production of iron ore by different countries places the United States above all others like a chimney above a mill. Curiously enough Canada, the nearest neighbor of the United States, is lowest in the scale of production. For 1903 the production was 35,019,308, valued at $66,328,415. — "The Mining World," August 27, 1904.

Protection of Steel Work. — In the construction of the new coal storage and handling plant at the New York Navy Yard, where the steel work is constantly exposed to the corrosive action of salt air, the Government engineers required that all the structural steel work be given a coat of the best red lead before leaving the shop, all contact surfaces an extra coat before assembling, and after erection two coats of dark green graphite paint. The corrugated galvanized iron was given two coats of graphite paint, the first dark green in color, the second slate. — "Engineering and Mining Journal," August 18, 1904.

The American Meeting of the Iron and Steel Institute. — Under date of August 31, 1904, the secretary of the Iron and Steel Institute has issued a circular describing the revised itinerary of the excursions of the Iron and Steel Institute in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TOTAL LAKE SUPERIOR PRODUCTION
MESABI RANGE
MARQUETTE RANGE
MENOMINEE RANGE
GOGEBIC RANGE
VERMILLION RANGE
IMPORT OF IRON ORE
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1,000,000
2,000,000
3,000,000
4,000,000
10,000,000
15,000,000
20,000,000
25,000,000
30,000,000
35,000,000
40,000,000

connection with the American meeting. It also gives the names of 203 members who have signified their intention to attend this meeting. The meeting will last from October 27 to November 9, and as previously stated the New York headquarters will be at the Hotel Astor.

The December number of *The Iron and Steel Magazine* will be published as a special issue devoted to the proceedings of this important meeting and will include the publications in full or abstracted of all the papers presented.

Electrometallurgy of Iron and Steel. — In a paper read before the Canadian Society of Civil Engineers and abstracted in the "London Electrical Review," of June 24, A. Stansfield discusses the possibilities of the various electric furnace processes for the preparation or refining of iron and steel. Relying on a large number of figures, he holds that electrical energy can be bought in Canada on a large scale at the price of about 0.15 cent per hp.-hour or 0.20 cent per kw.-hour. If, then, the reduction of one metric ton of pig iron from ore requires 2,500 kw.-hours, the cost of energy comes to $5.00. Against this may be set the price of fuel saved by using electric heat. This is about 0.6 ton of coke which, at $2.50 per ton, is equal to $1.50 per ton of iron. Thus, electric smelting of such ores as are capable of treatment in the blast-furnace cannot compete with the latter, even where very cheap water power is available, unless the price of coke is $8.00 per ton. There are, however, certain ores, such as iron sands and titaniferous ores which can only be treated with difficulty in the blast-furnace; for these the absence of the blast and the higher attainable temperature may render the electric furnace more useful. Moreover, refractory ores exist which can only be treated at all if they prove suitable for reduction in the electric furnace. Probably the greatest field of usefulness of the electric furnace, however, will be found in the production of crucible steel. He thinks that the electric manufacture of crucible steel is technically and financially possible in Canada; the energy might be developed from water power or by gas engines fed by blast-furnace gas. — "Electrochemical Industry," August, 1904.

REVIEW OF THE IRON AND STEEL MARKET

The iron and steel market has shown no important change in demand during September. Prices, also, have been substantially stationary except in the case of certain lines which are more or less completely controlled by pools and associations, and in these reductions were made as follows:

September 6: Structural shapes reduced $4.00 per net ton, to 1.40 cents for beams and channels 15 inches and under.

September 6: Plates reduced $4.00 per net ton on widths over 24 inches and not over 100 inches, and $6.00 on widths 6¼ to 24 inches inclusive.

September 19: Steel billets reduced from $23.00 to $19.50, and sheet bars from $24.00 to $21.50, making apparent reductions of $3.50 and $2.50 respectively, but the real reduction averaging less, on account of the discontinuance of the practice of quoting delivered prices which absorb a portion of the freight.

September 19: Merchant steel bars reduced $1.00 per ton, to 1.30 cents for Bessemer and 1.35 cents for open-hearth.

All these reductions were more or less nominal since the previous official prices had been shaded in one way or another. In the case of billets the former official price had been flagrantly violated even in transactions involving small tonnages. This was the case to a comparatively minor extent with sheet bars. In structural shapes it is a question whether prices were shaded directly, but there is no question that finished structural work was being furnished at less than the proper advance over the official prices for the shapes, for fabrication and erection. Plates were being shaded by outside mills on all ordinary widths. Merchant steel bars were going out on old contracts, made before the advance to 1.35 cents, and it is quite probable also to others, who had no contracts.

The general expectation in the consuming trade was that the reductions, anticipated for some time, would be greater than those which have been decided upon and there are therefore

some predictions that further reductions will have to be made before liberal buying can develop. There is no ground for positive predictions in this matter: demand for iron and steel products depends on too many influences, both obvious and recondite.

One prediction can be made with certainty, and that is that there will be no further important changes in prices of steel products before the end of the year; the interests which have made the recent changes have done so in the belief that the new prices should be satisfactory to consumers, and they will not meddle with the price structure until convinced by several months' experience that such revision is absolutely necessary. An exception, of course, must be made of rails, since the $28.00 price has remained since the spring of 1901 and has not been seriously considered as yet. The price is guaranteed to the railroads for this year, and there is little disposition shown to place contracts for next year. The rail matter will be taken up in due course, probably in December at the earliest.

There has been some improvement in demand, but no more than would be natural with the season; as a general proposition the period of slack demand in the iron trade is not ended nor is there indication that it will be before the end of this year. By common consent, on the other hand, 1905 is set down for a year of uniformly good demand, and a tonnage approximately equal to that of the past years.

Pig Iron. — In the last fortnight of August and the first fortnight in September there was a sharp movement towards the blowing in of additional blast-furnaces. The movement has now halted at the increased rate established early in September, and no further increase is likely this year. We estimate the production of all grades of pig iron in the United States in the first nine months of this year at 11,825,000 ± 25,000 tons, and production for the year at 15,750,000 ± 100,000 tons, compared with about 18,000,00 tons produced in each of the past two years. Pig iron sales have been somewhat heavier in the second half of September than at any time since the large purchases of Bessemer about the first of August in connection with the Pittsburg-Republic conversion deal, but the activity has been confined almost entirely to forge and foundry grades. Transactions were pretty well distributed throughout the country, and involved

no important price changes. Actual consumption of forge and foundry grades has not improved to any great extent. Consumption of Bessemer and basic grades has increased, but the increased make of steel is by interests which make their own pig iron, so that the market for these grades has not been affected. The most important single cause for the increased activity has been the necessity of completing all Canadian rail orders by November 30, as after that date the new duty becomes effective on contracts made prior to August 27, when the duty became generally effective. The new duty is practically prohibitive to American rails. We quote current prices as follows: F.o.b. Mahoning or Shenango valley furnace, Bessemer, $11.75 to $12.00; basic, $11.65 to $11.85; No. 2 foundry, $11.75 to $12.00; forge, $11.00. Delivered Pittsburg: Bessemer, $12.60 to $12.85; basic, $12.50 to $12.70; No. 2 foundry, $12.50 to $12.85; forge, $11.75 to $11.85. Delivered Chicago: No. 2 foundry, northern, $13.50 to $14.00; southern, $13.15 to $13.40. Delivered Philadelphia: No. 2 X foundry, $14.25 to $14.50; basic, $12.75 to $13.00. F.o.b. Birmingham: No. 2 foundry, $9.25 to $9.50; forge, $8.50 to $8.75.

Steel. — The new prices on billets and sheet bars are $19.50 for billets, 4 × 4 and larger, and slabs, $21.50 for sheet bars and small billets, long lengths, and $22.00 for sheet bars sheared to specifications, all f.o.b. Pittsburg, plus full rail freight to destination, except that Wheeling and valley deliveries are made at the Pittsburg price. Freight rates to important points are as follows: to Cleveland, $1.40; Chicago, $3.00; Philadelphia, $2.40; New York, $2.60; New England points, $3.00. The reduction at distant points is therefore much less than at Pittsburg, since under the old schedule, for instance, Cleveland took but 50 cents advance over Pittsburg, and Chicago only $1.00 advance.

Plates. — The reduction in plates is $4.00 per net ton on plates above 24 inches wide and $6.00 on plates 24 inches wide and under. The new prices are as follows for tank quality, one-quarter of an inch thick and heavier: 6¼ to 24 inches wide, inclusive, 1.30 cents per pound, f.o.b. Pittsburg, plus rail freight to destination, carload and larger lots; over 24 inches wide and not over 100 inches wide, 1.40 cents; extras for plates above 100 inches wide and under one-quarter of an inch thick. Boiler and

flange quality, $2.00 per net ton advance; marine, A. B. M. A. specifications and ordinary firebox, $4.00 advance. Prices cover both universal and sheared.

Bars. — The new prices on merchant steel bars are 1.30 cents per pound for Bessemer and 1.35 cents for open-hearth, f.o.b. Pittsburg, carload or larger lots, half extras. Through successive advances after the slump in 1900 prices reached 1.50 cents for Bessemer and 1.60 cents for open-hearth, in April, 1901. On April 1, 1902, an advance to 1.60 cents and 1.70 cents was made, but long time contracts had been booked and the advance really was not effective, a reduction being made November 6, 1903, to 1.30 cents for Bessemer and 1.40 cents for open-hearth. This was followed by an advance March 14, 1904, to 1.35 cents for Bessemer, open-hearth being left at 1.40 cents. The reduction this month therefore restores the former price on Bessemer, but places open-hearth a dollar a ton lower than any price officially made since about the beginning of 1901.

Shapes. — The new prices on shapes are as follows, all in carload or larger lots, f.o.b. Pittsburg: Beams and channels 15 inches and under, angles, 3×2 and 6×6 inclusive, and zees, 1.40 cents per pound; tees, three inches and larger, 1.45 cents; beams and channels over 15 inches, 1.50 cents.

Other Finished Lines. — There is no particular change to report. Wire products are held at 1.45 cents for plain wire and $1.60 for wire nails, both base, f.o.b. Pittsburg in carload lots to either jobbers or retailers, but in the west where there is competition from independent mills the Pittsburg basis is being shaded. Sheets are 2.10 cents for black and 3.10 cents for galvanized, No. 28 gauge, f.o.b. mill. Rails remain at $28 for standard sections, but light rails are firmer, being $20 to $22.

The Price of Iron Ores. — In our September number we reproduced a paragraph entitled "The Price of Mesabi Ores" from a usually accurate contemporary relative to prices realized at mines this year for Lake Superior ores. The paragraph contained an error, in intimating that from the market price at lower lake docks there should be deducted, to arrive at the price realized at mine, the rail freight, the lake freight, and the dock charges. The last named charges are involved in the freight, and do not have to be deducted separately, so that prices realized at mines would be higher by some 15 cents than computed in the para-

graph. As there have been changes in the market price and in the lake freight, which, by the way, slightly antedated the original publication of this paragraph, we present fresh and more complete figures bearing on the subject.

Lake Superior ores are customarily quoted at lower lake port, minimum current quotations being:

Old Range Bessemer	$3.00
Old Range non-Bessemer	2.75
Mesabi Bessemer	2.75
Mesabi non-Bessemer	2.35

Freight rates from the old ranges to the various shipping ports vary, as do the lake freights from these ports to the lower lake ports. In the case of the Mesabi range, however, the rail freight is uniformly 80 cents from any point in the range to the three shipping ports of the range, Two Harbors, Duluth and Superior, while the lake freight from any of these ports to Lake Erie ports is now well established at 65 cents, 70 cents having been the rate early in the season. Accordingly the price realized at mine for Mesabi ores is $1.45 less than the price at lower lake port, making Mesabi Bessemers net $1.30 at mine and Mesabi non-Bessemers 90 cents. The latter net price is no criterion, however, as it frequently happens in the ore trade that non-Bessemers have to be sacrificed, their mining being necessary in order to reach Bessemer grades. The 80-cent rail freight from the mines to upper lake ports is an extremely profitable one to the railroads.

STATISTICS

Production of Open-Hearth Steel in the United States in 1903. — Official figures of the production of steel ingots and castings by the basic and acid open-hearth processes in the United States have just been presented by the American Iron and Steel Association. The figures are as follows, in gross tons of 2,240 pounds, with the increase or decrease from the previous year:

	1903	Change from 1902
Basic open-hearth ingots and castings	4,741,913	+ 245,380
Acid open-hearth ingots and castings	1,095,876	— 95,320
Total open-hearth	5,837,789	+ 150,060
Basic open-hearth castings...........	134,879	+ 22,475
Acid open-hearth castings...........	249,930	— 5,545
Total open-hearth castings.........	384,809	+ 16,930
Open-hearth ingots only.............	5,452,980	+ 133,130

The production of Bessemer-steel ingots and castings, reported in our May issue, was 8,577,228 tons, so that the combined Bessemer and open-hearth production was 14,415,-017 tons, a decline from 1902 of 411,075 tons.

The production by states and districts was as follows in 1903:

Open-Hearth Ingots and Castings

	Basic	Acid	Total
New England	105,778	63,431	169,209
New York and New Jersey	71,537	33,061	104,598
Pennsylvania	3,557,493	884,865	4,442,358
Ohio	308,575	60,674	369,249
Illinois	390,513	32,406	422,919
Other States	308,017	21,439	329,456
Total	4,741,913	1,095,876	5,837,789

Open-Hearth Castings Only

	Basic	Acid	Total
New England, New York and New Jersey	5,311	30,783	36,094
Pennsylvania	14,483	150,749	165,232
Ohio, Illinois and other states	115,085	68,398	183,483
Total	134,879	249,930	384,809

Prior to 1896 the statistics of open-hearth steel production did not separate the basic from the acid product; it was only in 1895 that the basic process became really important in the United States. The statistics available are as follows:

Open-Hearth Steel Ingots and Castings

1869	893	1878	32,255	1887	322,069
1870	1,339	1879	50,259	1888	314,318*
1871	1,785	1880	100,851	1889	374,543
1872	2,679	1881	131,202	1890	513,232
1873	3,125	1882	143,341	1891	579,753
1874	6,250	1883	119,356*	1892	669,889
1875	8,080	1884	117,515*	1893	737,890
1876	19,187	1885	133,376*	1894	784,936
1877	22,349	1886	218,973	1895	1,137,182

	Basic	Acid	Total
1896	776,256	522,444	1,298,700
1897	1,056,043	552,628	1,608,671
1898	1,569,412	660,880	2,230,292
1899	2,080,426	866,890	2,947,316
1900	2,545,091	853,044*	3,398,135
1901	3,618,993	1,037,316	4,656,309
1902	4,496,533	1,191,196	5,687,729
1903	4,741,913	1,095,876*	5,837,789

Without any discussion of the relative amount of scrap used in basic open-hearth steel work, and the not altogether infrequent use of Bessemer pig on the basic hearth, the following figures may be interesting:

	Production of Basic Steel	Production of Basic Pig Iron	Percentage, Pig Iron to Steel
1896	776,256	336,403	43.3
1897	1,056,043	556,291	52.7
1898	1,569,412	785,444	50.1
1899	2,080,426	985.033	47.4
1900	2,545,091	1,072,376	42.1
1901	3,618,993	1,448,850	40.0
1902	4,496,533	2,038,590	45.2
1903	4,741,913	2,040,726	43.0

* The only years in which all previous records were not broken.

RECENT PUBLICATIONS

The Directory of the Iron and Steel Works of the United States; 16th edition; corrected to August 1, 1904; edited by James M. Swank, General Manager of the American Iron and Steel Association. 484 pages. The American Iron and Steel Association. Philadelphia. 1904. Price, $10. — The following extracts from Mr. Swank's preface will clearly show the contents of this book as well as the plan followed in compiling the information which it gives. The preface also contains comments and summaries of considerable interest to the iron and steel trades and those will be found reproduced in full elsewhere in the present issue of *The Iron and Steel Magazine.* Mr. Swank is to be congratulated upon the publication of so excellent and valuable a book.

"The American Iron and Steel Association presents herewith to the American iron trade another and thoroughly revised description of the blast-furnaces, rolling mills, steel works, and forges and bloomaries in the United States, the information contained in this edition of the 'Directory' being brought down to the latest possible date prior to its publication. The general plan of compilation adopted in the preparation of the 'Directory' for 1901 has been followed in the present edition, but it will be found upon examination of the present volume that the inquiries submitted to the manufacturers have been even more searching and more comprehensive than were then submitted. Whenever possible the history of each plant has been preserved, giving the date of its erection, with all subsequent additions to the plant, changes in ownership, if any, etc. In many instances the equipment of the plants has also been more fully described than in previous editions, and more attention has been given to the organization of companies, including capitalization and lists of officers. An exact system of cross references, adopted in previous editions, shows the relation of each plant to other plants under the same ownership, but this feature has been enlarged in

the present edition. The alphabetical arrangement of previous editions is retained. A comprehensive table of contents and a most complete index will be appreciated by all who will have occasion to consult this edition of the 'Directory.' With two unimportant exceptions, every line of information contained in these pages has been obtained directly from the manufacturers and is given publicity by their authority.

"Part I of the present edition, occupying 188 pages, embraces descriptions of the United States Steel Corporation and of the operating companies and all the properties that are under its control; also of all the independent companies whose capitalization, lists of officers, etc., as well as the descriptions of their plants, often very elaborate, are naturally looked for in a prominent part of a volume of the scope of the 'Directory.' Some companies which, through lack of information or from other causes, were included in Part II of the 1901 'Directory' are now transferred to Part I. The descriptions in this division of the 'Directory' embrace coal and iron ore mines, coking plants, limestone quarries, railroads, lake vessels, etc., as well as the blast-furnaces, rolling mills, and steel works. All the properties of the United States Shipbuilding Company are described. Many changes in the ownership as well as in the equipment of plants described in Part I and Part II of the 'Directory' for 1901 will be noticed in the present edition, further consolidations of ownership being a particularly noticeable feature.

"Part II, occupying 186 pages, embodies a description of all iron and steel works in the United States that are not described in Part I, and it also gives the name and address of every company which manufactures iron or steel that is described in Part I, thus presenting a continuous and complete list of all the iron and steel works in the country. In Part II the arrangement is by states and districts, as in the edition for 1901, blast-furnaces coming first, followed by rolling mills and steel works and forges and bloomaries. Part II also contains a list of recently abandoned or dismantled iron and steel works and of long inactive plants.

"Part III, occupying 66 pages, classifies for ready reference the leading products of the rolling mills and steel works, the arrangement being by states. It includes the Bessemer steel works, the open-hearth steel works, the crucible steel works, the steel casting works, the rail mills, the structural mills, the wire-rod

mills, the skelp mills, the plate and sheet mills, the black plate mills, and the tinplate and terne plate works.

"This edition of the 'Directory,' which embraces exactly 484 pages including the index and which forms a larger volume than any of its predecessors, does not contain some classified lists of minor iron and steel products and of iron and steel consumers that may be found in previous editions. These omitted lists will all be found in the Supplement to the 'Directory' for 1901, which was issued in 1903.

"Part IV, occupying 28 pages, contains information concerning changes in officers, ownership of plants, etc., that occurred while the main part of the 'Directory' was passing through the press; also the index to the 'Directory.'"

The Journal of the Iron and Steel Institute, No. 1, 1904; edited by Bennett H. Brough. 768 pages; numerous illustrations. E. & F. N. Spon. London. — This volume includes the minutes of the proceedings of the May (1904) meeting of the Institute, held in London, and the usual excellent "Notes on the Progress of the Home and Foreign Iron and Steel Industries." The following papers with their discussions are printed in this volume: "Explosions Produced by Ferro-Silicon," by A. Dupré and M. B. Lloyd; "The Manufacture of Pig Iron from Briquettes at Herräng," by Henry Louis; "Notes on the Production and Thermal Treatment of Steel in Large Masses," by Cosmo Johns; "Pyrometers Suitable for Metallurgical Works," report of a committee appointed by the Institute; "The Manufacture of Coke in the Hüssener Oven at the Clarence Iron Works and Its Value in the Blast-Furnaces," by C. Lowthian Bell; "The Range of Solidification and the Critical Ranges of Carbon-Iron Alloys," by H. C. H. Carpenter and B. F. E. Keeling; "Troostite," by H. C. Boynton; "The Synthesis of Bessemer Steel," by F. J. R. Carulla; "The Thermal Efficiency of the Blast-Furnace," by W. J. Foster; "The Plastic Yielding of Iron and Steel," by W. Rosenhain; "The Use of Steel in American Lofty-Building Construction," by B. H. Thwaite; "The Relations Between the Effects of Stresses Slowly Applied and of Stresses Suddenly Applied in the Case of Iron and Steel," by Pierre Breuil (abstract); "The Influence of Varying Casting Temperatures on the Properties of Steel and Iron Castings," by P. Longmuir.

The Journal of the Iron and Steel Institute, Supplement to Vol. LXV. "Relation Between the Effects of Stresses Slowly Applied and of Stresses Suddenly Applied in the Case of Iron and Steel, Comparative Tests with Notched and Plain Bars," by Pierre Breuil. 151 pages, 23 plates and 60 illustrations in the text. E. & F. N. Spon. London. 1904. — This volume contains the full report of Mr. Breuil to the Iron and Steel Institute of the investigation he conducted as a Carnegie research scholar and for which he was unanimously awarded the gold medal by the council of the Institute.

Rustless Coatings, by M. P. Wood. 432 9 × 5½-in. pages; 85 illustrations. John Wiley and Sons. New York. 1904. Price, $4.00. — At no other time was the question of protective coatings for iron and steel structures given so much attention by metallurgists and engineers as at the present day. The question is a momentous one. Costly structures representing millions of dollars are being slowly destroyed for lack of a sufficiently effective rustless coating. The steel cars now being so widely used afford a striking instance of this character. Mr. Wood's excellent book is, therefore, a timely one and should be welcomed by all those interested in protective coatings for metals. The author treats its subject exhaustively and with much authority. Its chapters on the corrosion of iron and steel and of the action of electrolysis we find of special interest. The book is printed on excellent paper, well bound and its typography could hardly be improved.

The Industrial and Artistic Technology of Paint and Varnish, by A. H. Sabin. 372 9 × 5½-in. pages; illustrated. John Wiley and Sons. New York. 1904. Price, $3.00. — The author of this book is a well-known authority on the subject of paint, varnish and protective coatings in general, and his work will prove of great value to many members of the engineering profession. His chapter on "Protection of Metals Against Corrosion" will be found of special interest to iron and steel metallurgists and engineers whose attention is at present forcibly called to this momentous question.

Methods of Chemical Analysis and Foundry Chemistry, by F. L. Crobaugh; second edition. 109 5 × 6¾-in. pages. Pub-

lished by the author. Cleveland, Ohio. 1904. Price, $2.00. — The author describes the chemical methods for the analysis of iron and steel which he has found most satisfactory in his own laboratory. The second part is devoted to foundry work and deals with the following subjects: Variations in pig iron, scrap and sheet iron, coke and coal, figuring mixtures, white and chilled castings, malleable castings, chilled rolls, machinery castings, other gray iron castings, annealing castings, influence of elements on cast iron and relation of chemist to foundryman.

Les Aciers Spéciaux (Special Steels), by Léon Guillet, with a preface by H. Le Chatelier. 100 9 × 11-in. pages; numerous photomicrographs and other illustrations. Vve. Ch. Dunod. Paris. 1904. Price, 10 francs. — This book includes the excellent papers on nickel-steel, manganese-steel, and silicon-steel published by Mr. Guillet in the "Bulletin de la Société d'Encouragement" and in the "Revue de Métallurgie." They will be welcomed by metallurgists in their present form. Mr. Guillet has shown himself to be a methodical and skilful manipulator, his micrographic work especially being of a high degree of excellence. His researches were conducted in the laboratory of the Dion & Bouton Co., and many of the special steels needed were prepared especially by the steel works of Unieux and by the Imphy works.

Leçons sur l'Electricité Professées à l'Institut Electrotechnique Montéfiore, Annexé à l'Université de Liège, by Eric Gérard; Vol. I: "Théorie de l'Electricité et du Magnetisme; Electrometrie; Théorie et Construction des Générateurs Electriques," seventh edition. 822 6½ × 10-in. pages; 400 illustrations; paper covers. Librarie Gauthier Villars. Paris. 1904. Price, 12 francs. — The fact that this is the seventh edition of this work is a conclusive evidence of the favor with which it has been received. Its author, who is director of the Montéfiore Electrotechnique Institute at Liège (Belgium), ranks among the most distinguished students of electrical science. The authority, method and clearness of his treatment cannot fail to be appreciated by the student. We must express our regret that so bulky a book be issued in paper covers.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

765,706. Process of Case-Hardening. — Carlo Lamargese, Rome, Italy. A step in the art of case-hardening iron and steel which consists in first mixing together wood-charcoal and lampblack; in then placing the article in a mass consisting alone of this mixture with its metallic surfaces in intimate contact with the latter, and in then heating the article and the surrounding mixture.

765,724. Treating Scrap-Steel and Recarburizing Same. — Herbert B. Atha, East Orange, N. J. A process for preparing scrap-steel for remelting in an open-hearth furnace, which consists in intimately mixing with the scrap-steel finely divided carbon.

765,789. Process of Converting Furnace-Flue Dust into Blocks. — Samuel V. Peppel, Columbus, Ohio. A process of converting flue-dust of a furnace or finely divided ore into blocks, consisting of mixing a quantity of flue-dust or fine ore with water and lime substantially in the proportions stated, adding to such mixture a desirable quantity of ammonium chloride, pressing the mixture into blocks and subjecting said blocks to a hardening process.

765,932. Manufacture of Cast-Steel. — Maurice Meslans, Paris, France. A process for removing oxygen, nitrogen and hydrogen from steel in the process of casting, consisting in incorporating with the molten steel an alloy of aluminium and calcium.

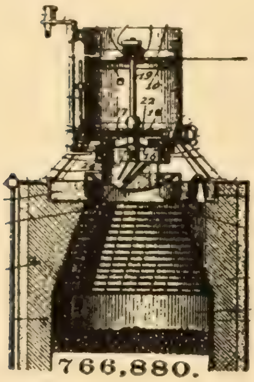
766,131. Treating Scrap-Steel and Recarburizing Same. — Herbert B. Atha, East Orange, N. J. A process for preparing scrap-steel for remelting or recarburizing in an open-hearth furnace, which consists in applying to the surface of the scrap a carbon-bearing liquid.

766,434. Rolling-Mill. — Victor E. Edwards, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass. In a rolling-mill, the combination of a repeater having a portion of its side movable, and means for varying the angle which said movable portion makes with the plane of the repeater.

766,732. Valve Mechanism for Blowing-Engines. — Edwin G. Rust, Pueblo, Colo. The combination in a compressor of a cylinder, a piston, a head for said cylinder including a structure provided with a plurality of cylindrical surfaces having ports in them, independent inlet and discharge valves coacting with said ports, and operating mechanism

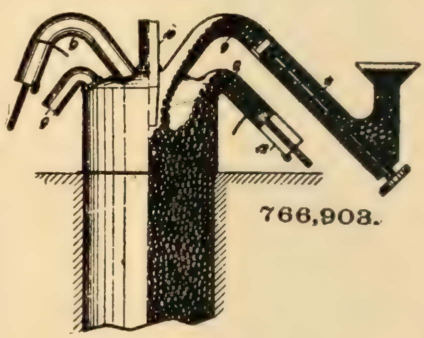
connected to the valves, there being also in the head a port or ports opening into the cylinder and placed to serve as the common means of communication between the ports of said surfaces and the cylinder.

766,880. Gas Producer. — Jerome R. George, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass. In a gas producer, the combination with a heating chamber provided with an opening in its top for the admission of coal, of a coal reservoir located above and over said opening and having an opening in its bottom for the delivery of coal, a rotating coal distributor between said reservoir and the producer chamber, said distributor consisting of a hopper-shaped spout with its upper or admission end concentric with its axis of rotation and of greater area than its lower or delivery end which is eccentric to said axis of rotation, with the inclined side of said hopper-shaped spout at an angle to a vertical plane whereon coal will flow freely by the force of gravity alone.



766,880.

766,903. Charging Device for Furnaces, Gas Generators, Etc. — Arpad Ronay, Budapest, Austria-Hungary. A charging device for a furnace, comprising a bent charging tube having a branch connected with the furnace, and a mechanical charging device in the other branch of the tube, the arrangement being such that the fuel in the bent elbow portion of the tube closes the same to prevent the escape of gas and also protects the mechanical charging device against the heat of the furnace.



766,903.

767,110. Method of Making Magnetic Materials. — Robert A. Hadfield, Sheffield, England. A method of producing a magnetic material of high permeability and low hysteresis action, which consists in alloying a magnetic substance with silicon reducing the alloy to a thin body, heating such thin body to a temperature below its melting-point, allowing it to cool, reheating it to a temperature above that first employed, and again allowing it to cool.

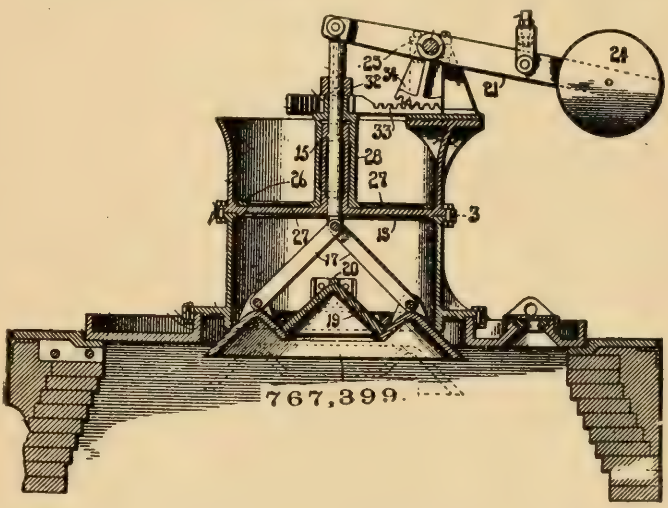
767,243. Continuous Heating-Furnace. — Josef Reuleaux, Wilkinsburg, Pa., assignor to Alexander Laughlin, Sewickley, Pa. A continuous heating-furnace provided with receiving and discharge openings, bearings for a line of slabs or billets extending from the receiving opening to the discharge opening and having inclined portions, a fuel port opening into such furnace at a point beneath and intersecting said inclined portions, a cinder pocket in line with the entrance of such port into the furnace, and

means opening into the port intermediate the upper end thereof and said cinder pocket for supplying fuel to said port.

767,285. FURNACE-VALVE. — Julian Kennedy, Pittsburg, Pa. A valve for furnace flues comprising a gas flue, a disk member adapted to move edgewise in the flue into closing position, and a movable clamp aligned with the middle of the valve-seat and adapted to bear upon the disk member to hold it to its seat.

767,314. ROLLING-MILL. — Johann Sandner, Düsseldorf, Germany, assignor to Anton Ricards, Düsseldorf, Germany. In a rolling-mill, a series of pairs of parallel overlapping rings arranged to form a progressively-reduced opening, in combination with oppositely-placed driving-wheels engaging said rings.

767,399. FEEDING DEVICE FOR GAS PRODUCERS, FURNACES, OR THE LIKE. — Samuel Porter, Pittsburg, Pa., assignor to Porter-Miller Engineering Company. In a feeding device for gas producers and the like, an upper drum, a lower drum, a bell for closing one drum and a rotary gate for closing the other drum, and means for operating said bell and gate simultaneously.



767,730. ROLLING-MILL FEED MECHANISM. — Charles W. Bray, Pittsburg, Pa., assignor to American Tin Plate Company. A tandem mill having two sets of rolls, an inclined table leading from the first set, and an automatic feed mechanism arranged to transmit the metal from the incline toward the second set of rolls.

767,731. METHOD OF ROLLING BLACK PLATES OR SHEETS. — Charles W. Bray, Pittsburg, Pa., assignor to American Tin Plate Company, Pittsburg, Pa. A method of rolling black plates or sheets, consisting in superimposing two or more bars to form a pile, moving the piles successively through a continuous heating-furnace, separating the bars, rolling said bars separately and successively, and then forming the separately-rolled plates into a pack.

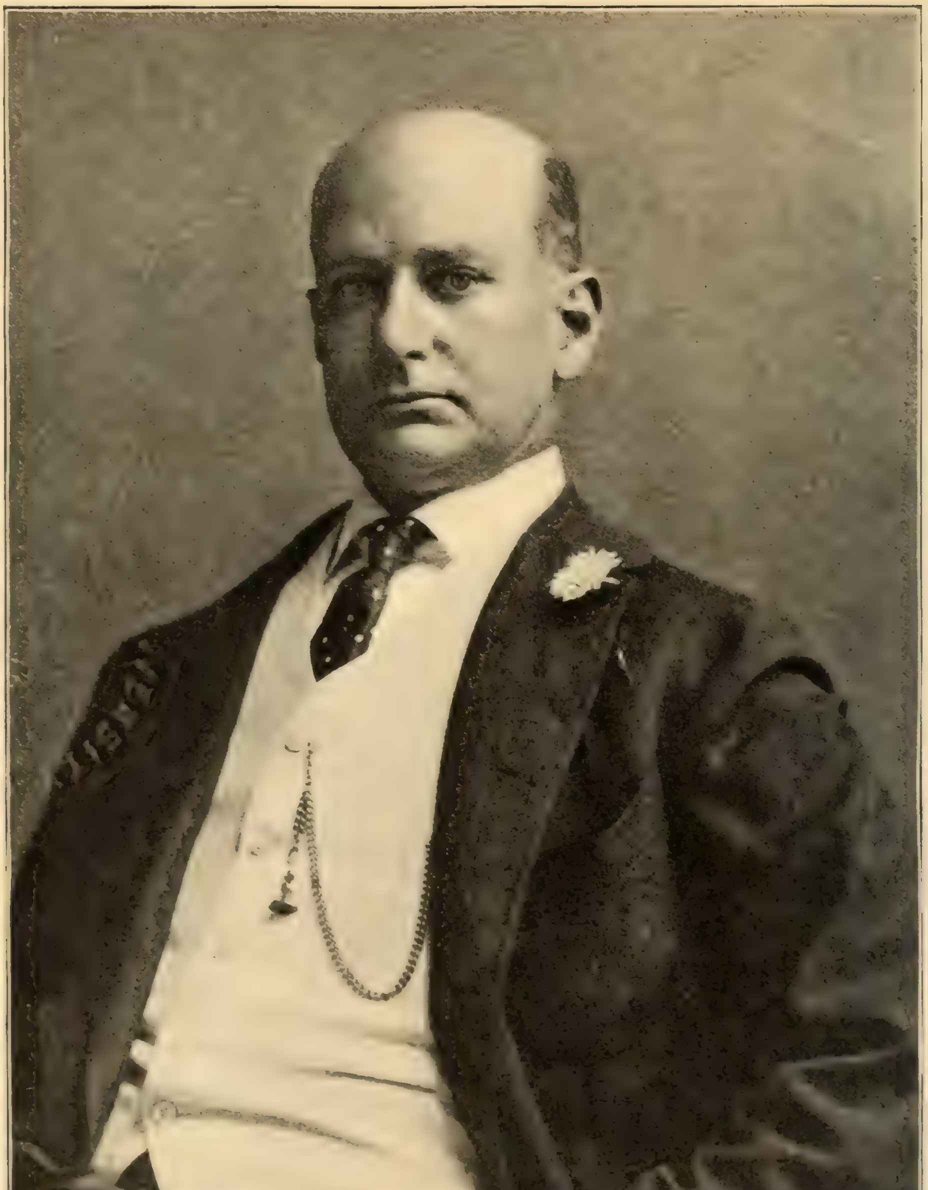
767,840. REGENERATIVE GAS REHEATING-FURNACE. — Frederick Siemens, Dresden, Germany. A regenerative gas reheating-furnace having primary and secondary chambers in communication with each other for the passage of billets, blooms or the like from the primary to the secondary

chamber, means whereby a gas-flame is directed across one of said chambers above the bed thereof and between the ends of said bed, said flame being of a gradually-increasing temperature from one end of said bed to the other, and means for heating the other furnace chamber.

GREAT BRITAIN

17,445 of 1903. Iron-Ore Briquette. — T. Rouse and H. Cohn, London. Making briquettes of fine iron ores by mixing with dilute solution of silicate of soda and hardening by means of steam and hot air.

12;000 of 1904. Copper-Steel Plates. — H. Harmet, St. Etienne France. Method of making compound plates of copper and steel, by compressing the liquid steel upon the sheet of copper in the molds.



MAUNSEL WHITE

SEE PAGE 465

The Iron and Steel Magazine

"\. . . . . . *Je veux au mond publier*
d'une plume de fer sur un papier d'acier."

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NOTES ON PROCESSES FOR PRODUCING OPEN-HEARTH STEEL*

By R. M. DAELEN

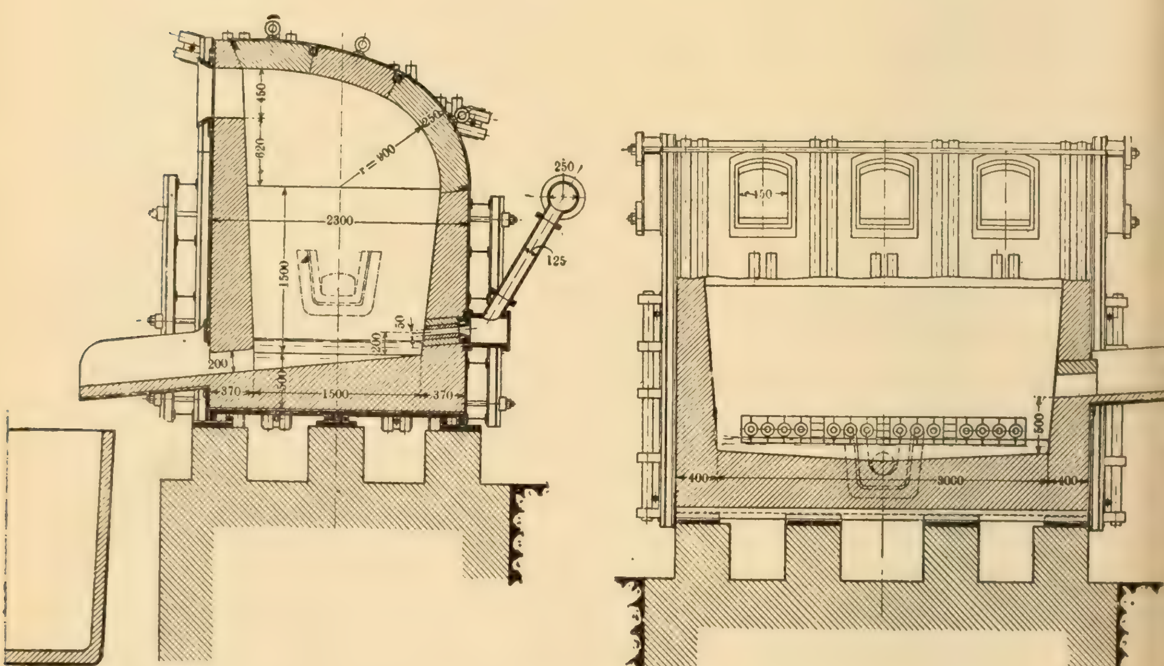
Düsseldorf

THE present article is chiefly written for the purpose of making a comparison between the basic-Bessemer and the open-hearth processes. The latter can only be taken into consideration so far as it is adapted for the conversion of pig iron delivered in a liquid condition from the blast-furnace. The melting down of iron scrap in large quantities charged cold, with the addition of a little pig iron, can in future be worked with economical success only by works which consider it as a secondary working department along with the basic-Bessemer process, and with the disappearance of the latter it would lose a great deal of its importance, since a large proportion of the scrap is derived from that process.

For the production of pig iron the blast-furnace will always remain the most suitable apparatus, so far as technical practice and science are to-day able to judge. For if, on the one hand, the experiments made with a view to replacing the blast-furnace by a process of working the reduced ore directly into welded or ingot iron cannot be regarded as altogether hopeless, on the other hand, for such a method only special kinds of ore can be taken into

* "The Iron and Coal Trades Review," June 24, 1904; slightly abridged.

consideration, since the great bulk of the ores can only be properly reduced in the blast-furnace. The principal object in the production of ingot iron, therefore, always consists in the elimination of the foreign bodies contained in the pig in too great a proportion, especially of carbon, silicon, sulphur, and phosphorus, for which the simplest method is the oxidation by atmospheric air, after Bessemer's process. In the case of pig iron made according to determined local conditions, and which does not correspond to the requirements of the Bessemer process — requiring, consequently, to be finished in the open-hearth furnace — the idea has been



Figs. 1 and 2. Sectional Elevations of Converter Used at Krompach.

conceived of employing the former process for the preliminary refining of the pig iron taken in liquid state directly from the blast-furnace, and to charge the product thus obtained into the open-hearth furnace. This combined process, called the "Duplex-Process," was first carried out on a large scale at Witkowitz (Moravia), in the year 1878, where it is still operated to-day with good results. The ores existing at Witkowitz contain too much phosphorus for the acid, and too little for the basic-Bessemer process, and hence the preliminary refining is performed in the acid converter and the finishing melting in the basic open-hearth

furnace. After all that has become known about it, however, this process has not found any further development, because the erecting and working costs of both a complete Bessemer and an open-hearth plant are too high, and only in exceptional cases, as at Witkowitz, are they justified by the local conditions.

In order to meet these difficulties, Mr. L. Pscholka, of Vienna, and the writer conjointly have undertaken experiments in which the pig iron undergoes a preliminary refining directly at the blast-furnace by using the hot blast air of the latter, which, on account of its low pressure, is introduced laterally into the converter,

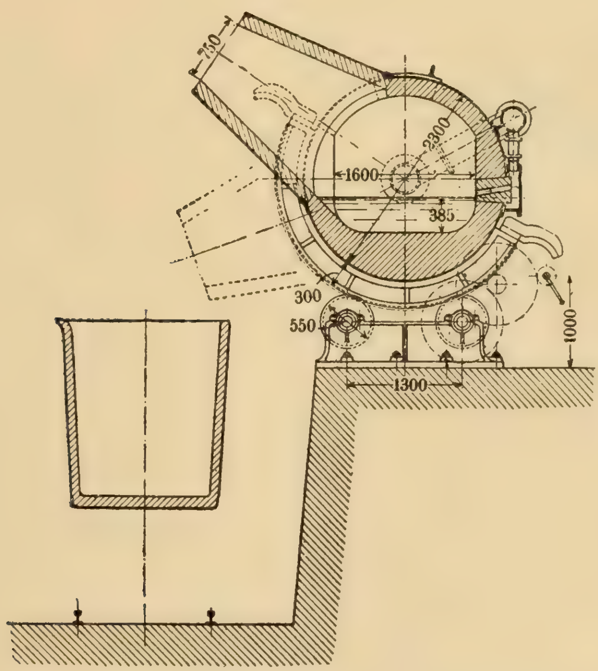


Fig. 3. Sectional Elevation of Converter Used at Rheinhausen.

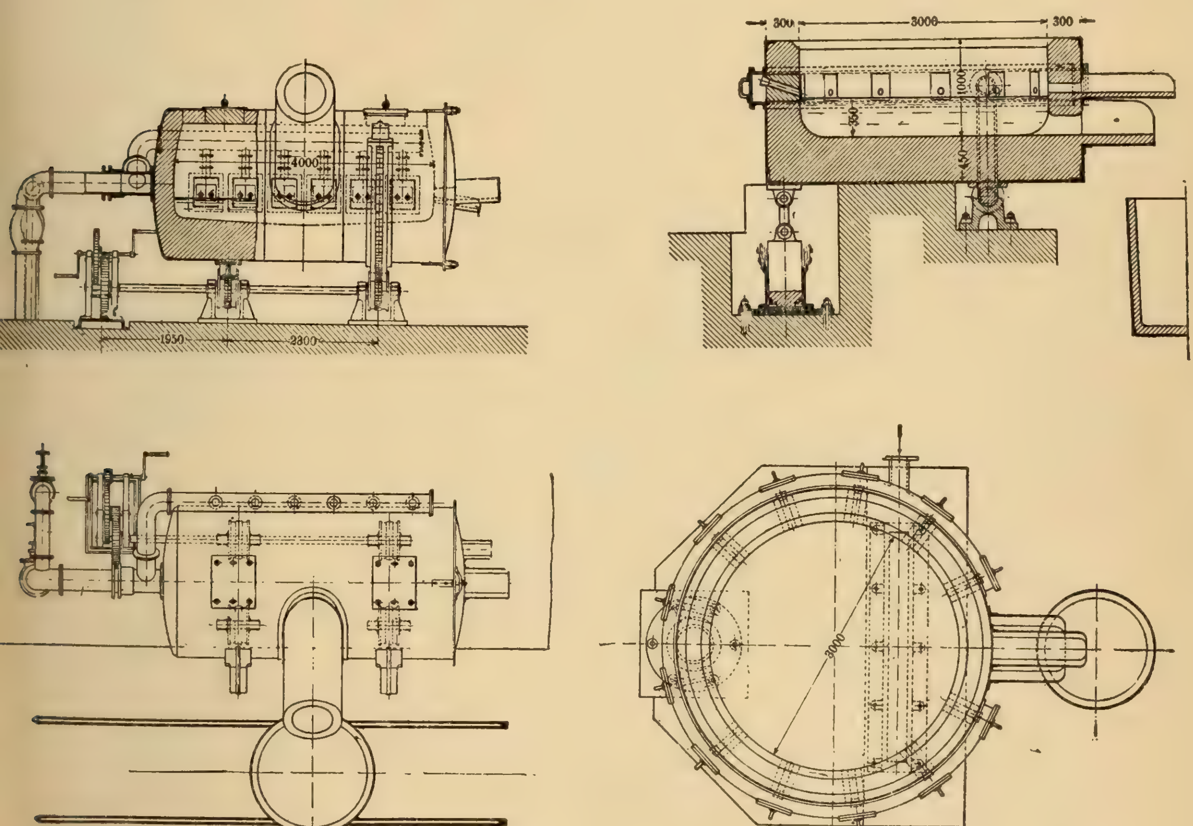
where it serves to blow over the pig-iron bath. To effect this the simple box-shaped converter, shown in Figs. 1 and 2, was constructed for a capacity of ten tons and erected at Krompach (Hungary). This gave good working results, as will appear from the following account. The working expenses for the preliminary refining were not high at Krompach, but they could not be exactly calculated, because the existence of only one blast-furnace for the puddling and open-hearth steel work did not allow of regular working. With pig iron containing C, 3.5 per cent; Mn, 22 per cent; and Si, one per cent, a waste of 7.29 per cent in

bringing the carbon down to about one per cent at the preliminary refining must be considered as moderate. The consumption of coal for the production of steam was much less than at Witkowitz, where it was 155 kilos (three cwt.) per ton of steel, because the speed of the blowing engine was, during the operation of refining, only increased about 20 per cent which, with boilers heated by blast-furnace gas, is hardly noticeable. The principal advantage, however, consisted in the reduction of the cost of the finishing process of melting in the open-hearth furnace; for if with the ordinary scrap melted with cold charges and containing one per cent of carbon, there could be obtained six meltings within 24 hours, seven such meltings may certainly be reckoned upon in regular working with liquid preliminary-refined pig iron, in addition to which the reduction of coal consumption in the open-hearth furnace is considerable, amounting as it did to 150 kilos (three cwt.) per ton of output, compared with 250-280 kilos (5 to 5½ cwt.) with the scrap melting. The saving under this head will serve as a measure of the decrease in the total working expenses. As the cost cannot be considered as too high, this process would seem to be worthy of recommendation in certain cases, for local conditions in Germany vary very considerably. It has, however, unfortunately been impossible hitherto to produce exact returns based upon figures obtained by regular working.

Further trials which were made at Czenstochau and Rheinhausen have not led to a definite success in this direction, as they were given up too early owing to failure of the refractory lining of the converter. The latter was of the shape shown in Fig. 3; its capacity was 20 tons, and it had a basic refractory lining. On account of its capacity being double that at Krompach, the temperature in the converter was considerably higher, and the destructive effect of the pointed flames, produced by the CO_2 gas and the hot air, upon the nozzles in the opposite wall was so great that it was not possible to give it a solidity sufficient to allow of regular working.

This experience led the writer to the idea of giving to the converter the circular shape, with radial or tangentially-placed nozzles, shown in Figs. 6 to 8, so that the pointed flames meet each other in the center and cannot produce a destructive effect upon the wall. By this method the greater part of the surplus production of heat passes into the bath. Since the temperature

in the experiments mentioned was too high in the new converter it might be turned to some useful purpose. This would be best effected by the addition of more iron ore, which would accelerate the process and increase the yield. Unfortunately, the writer did not succeed in carrying out his idea in practice, though there does not seem to be any difficulty from a technical point of view. Probably, the chief reason lay in the circumstance that meanwhile several other new processes for working liquid pig iron in the open-hearth furnace without preliminary refining had begun to attract the attention of ironmasters.



Figs. 4, 5, 6 and 7. Sectional Elevations and Plans of Converters with Blast Nozzles Designed to Avoid Destructive Effects Upon the Lining, etc.

Subsequent to the oldest process — the so-called pig-iron ore process — trials were made about 30 years ago, by Dr. Siemens, at Swansea, among others, to produce ingot iron and steel in the ordinary open-hearth furnace with pig iron either alone or mixed with iron scrap with the addition of pure rich iron ore, but without much success, because the duration of each heat was too long

and the daily production per furnace was too small. The later introduction of the basic furnace with liquid pig iron showed no considerable progress, so that the process has not found further extensions, and where it is still operated it is very likely to be replaced by one of the new processes, as soon as the question of adaptability is decided, for which, of course, the local conditions in each separate case have to be taken into consideration.

The oldest of these newer processes is that known as the Bertrand-Thiel, consisting essentially in the application of several furnaces, which serve partly as preliminary refining and partly as finishing melting furnaces, and by which a considerable acceleration of these separate operations is achieved. As to the advantages which are thereby obtained, Mr. Thiel related them very fully

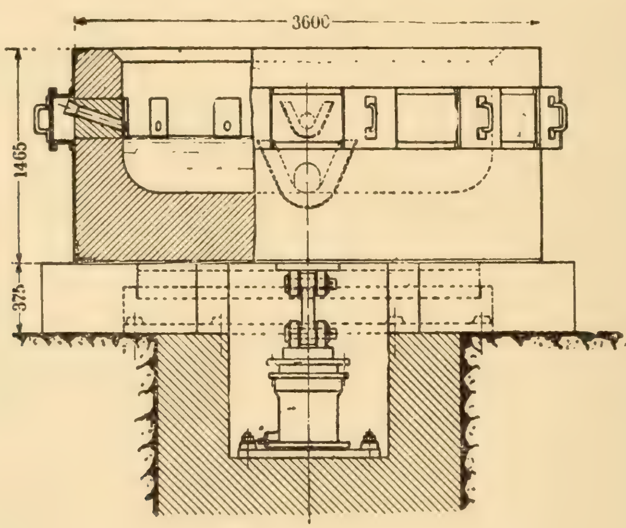
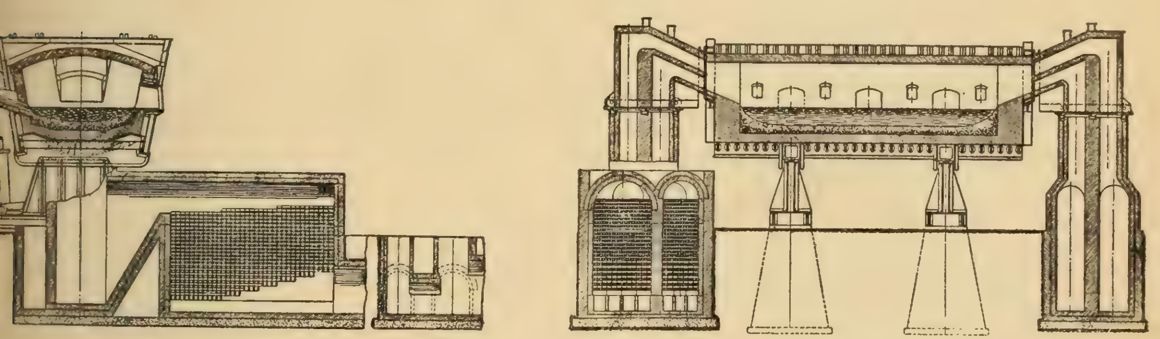


Fig. 8.

several years ago, so that I can turn now to the later process, the so-called continuous-melting process of Benjamin Talbot, which, on its first introduction about four years ago attracted the attention of ironmasters to a great degree. By it both the size and daily output of an open-hearth furnace were increased to figures which had formerly not being imagined possible, and by which the prospects of an economical success, compared to the basic-Bessemer process, seemed to become much more favorable. The Talbot process is based principally on the furnace having a capacity four times larger than that of the casting ladle, so that after each tapping there still remains about three-fourths of the

iron bath. By the addition of a corresponding fresh quantity of liquid pig iron, the contents are replenished, and then the refining and melting operatitons are again pursued for the next tapping. (See Figs. 9 and 10.)

At first sight it certainly seems somewhat curious that such a furnace of 100 or 200 tons capacity should work better and cheaper than an ordinary one of 25 and 50 tons, but for the explanation of this fact the pig-iron and ore process must be taken into comparison, because in both cases a preponderating quantity of liquid pig iron is employed. In the latter there are obtained two to three meltings within 24 hours, whereas Talbot obtains four to five, besides a higher yield of iron from the ore with less consumption of fuel. The reason for this lies chiefly in the greater



Figs. 9 and 10. Sectional Elevations of the Talbot Converter.

amount of heat accumulated in the iron bath, available for the physical or chemical actions which take place there, and by which they are accelerated. The extremely favorable effect of the heat in this direction is a well-known fact, and in this instance it is especially powerful from the great surplus accumulated on the open hearth, as the following statement shows:

Coal required per ton of steel, 300 kilos.		
One kilo of coal gives 8,000 calories.		
Production of heat 300 × 8,000 calories................		2,400,000 calories
Heat required for bringing one ton of liquid iron from 1,200° C. up to 1,600° C., 400 × 1,000	400,000	
Heat required for melting 25 per cent of slag 46 ×250	11,500	
		411,500 calories
Remainder		1,988,500 calories

The loss of heat by radiation in an open-hearth furnace is difficult to determine; it therefore can only be estimated. Taking the loss at a very high figure, say, at about half the amount of the above remainder, there remain in round figures some 1,000,000 calories for the increase of the temperature of the bath, and as the capacity of the latter is four times larger than the amount tapped, on which the 300 kilos are reckoned, there remains for each ton about 250,000 calories, and as the specific heat of liquid steel is 0.2, so the existing amount of heat would be sufficient for raising the temperature of the bath by about 1,250° C., which, of course, is practically impossible. But it follows from this that the superheating is as great as possible, and as the temperature in the open-hearth furnace is about 400° to 500° C. higher than the melting point of steel, so the large bath in the Talbot furnace will doubtless undergo a considerable superheating, the more so as this is much assisted by the extensive surface and small thickness of the slag cover. This is confirmed by the great rapidity with which all the chemical and physical operations are effected, which fact is especially noticeable when pouring in fresh pig iron, as thereby such a heavy production of CO gas takes place that it escapes through the door, burning outside with a very active flame. The iron ore which is added after every tapping is liquified with great rapidity, and yields oxygen to the bath in quantity sufficient to allow of this vigorous reaction taking place so shortly afterwards.

If thus the great working capacity of the Talbot furnace is explained in general, so it is in particular respecting the yield of iron from the ore, as by the addition of about 20 per cent to the charge of iron the yield is brought up 107 per cent, which is equivalent to a gain of metal of 90 per cent, which, compared to the pig-iron process in the ordinary furnace, is extremely advantageous, amounting as it does in the latter to only about 60 per cent. The rapid reduction which is thereby obtained is yet further favored by the dilution of the bath, due to the pouring in of the liquid pig, owing to which the average content of carbon, silicon, and phosphorus amounts only to one-seventh that of the pig iron. In his statement, Mr. Talbot says that it is advantageous to keep the carbon content always under 0.5 per cent, and, therefore, he divides the charge of liquid pig iron into two equal parts, to be charged one after the other.

At a price of 15*s.* per ton, ore containing 60 per cent of iron will cost in the charge about 30*s.* per ton. If we remember that the cost price of pig iron is 45*s.* it will be evident how great the advantage is when the amount of ore added is large. This is limited by the quantity of reducible bodies, C, Si, and P, contained in the bath, and it can, therefore, be understood how the efforts to increase the addition of ore have at repeated times led to the proposition to introduce carbon also into the bath; but that, apart from the difficulty of forcing it under the slag covering, owing to its low specific weight, has the inconvenience of delaying the melting operation. This is because there are two different operations necessary, viz., first, the absorption of the carbon by the iron, and, secondly, its combustion by the aid of the oxygen of the ore. Since, therefore, the daily production of the furnace would be reduced, and the working cost correspondingly increased, there are no prospects of success for such a process, and it is clear that the only way to attain the object in view is by reducing the ore in a separate furnace previous to the charging, so that the iron thus produced performs the same part in this furnace as scrap does in melting it in conjunction with pig iron.

Against this proposal it might be objected that the addition of binding material (limestone, etc.) required for the making of ore coal-briquettes for the reducing furnace would produce too great a quantity of slag; but to this it may be replied that an increase in the ore addition of, say, only 20 to 40 per cent would be already sufficient in itself to reduce the cost of production under that of the basic-Bessemer process, since thereby the yield would be increased to about 115 per cent of the charge of metal; and this without any considerable augmentation of the working costs, because there is plenty of heat for melting, the more so as the reduced ore briquettes are charged at a temperature of 1,000° C. The reduction of the iron ore, therefore, is not done here in order to replace the open-hearth furnace, but in order to decrease, as far as possible, the cost of production of the ingot iron, so that powdery ore can be used, which is not very suitable for the blast-furnace, and, therefore, has been up to now of little value, although it is often both pure and rich.

In all trials which have hitherto been made in the way of direct production of iron from ores alone in the open-hearth furnace — which, among others, have been conducted on a large

scale by the Carbon Iron Company of Pittsburg — it has always been the rule to work the iron product in the same manner as a loop bloom from a puddling furnace, or to melt the minute briquettes formed of spongy iron and binding material in the open-hearth furnace; but this was always accompanied by such waste, that it was not possible to obtain an economical result. Hence a general prejudice followed, which, however, is only justified as regards the latter method; the more so as with the former the burning away of the spongy iron is avoided by the plunging and rapid melting in the Talbot furnace.

Regarding the latter, it may be observed that among German ironmasters one sometimes meets with the objection that it is not possible to produce a uniform good quality, if the additions for the recarburization are put in the ladle after tapping. If some of the reports which have been given by German ironmasters and engineers — who have visited and inspected the process in operation at Frodingham and elsewhere — do not give any occasion for such a supposition, it must be added by way of explanation that in the Talbot furnace the decarburization is not carried so far as in the ordinary open-hearth furnace, because a sufficient dephosphorization takes place previously if the phosphorus content of the pig iron is not more than one per cent. Thus a more advanced stage is obtained, owing to which a smaller addition of ferro-manganese and ferro-silicon, with coal, is sufficient in order to obtain the required quality. But in a pig iron, with 1.8 per cent of phosphorus, as at Frodingham, with which, in order to obtain a dephosphorization down to 0.09 per cent, the decarburization must be pushed to 0.07 per cent, the recarburization in the ladle with ferro-manganese and coal gives a very satisfactory result, as shown in the reports given by Mr. Surzychi, of Czenstochau, among others. The uniform performance of this operation is assured also in the continuous process by the high temperature, which, owing to the large amount of heat contained in the bath, is always higher than in the ordinary open-hearth furnace.

The basic-Bessemer process further presents in this direction some analogy for comparison, for if in this case also the addition of the recarburizers is made in the converter, a still greater quantity is necessary, and the tapping into the ladle is done so quickly afterwards that there is scarcely any difference in the mixture.

Here also the high temperature is the principal point, the best proof of which can be seen in the circumstance that the requirements of quality can only be fulfilled if there is always an uniform heat in the meltings.

SPECIAL FORMS OF BLAST-FURNACE CHARGING APPARATUS*

By T. F. WITHERBEE

Durango, Mexico

THAT the single charging bell, properly proportioned, is a good all-around device for distributing the material in a blast-furnace can scarcely be questioned; yet it is equally true that, in some cases, it has not given perfect satisfaction. This has been demonstrated by the use of double bells, at furnaces under the best management, generally in cases where anthracite,

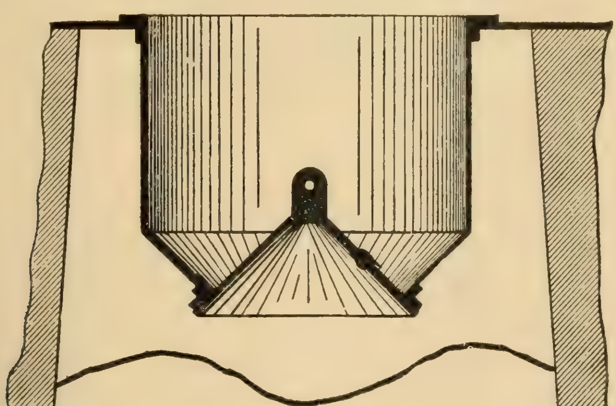


Fig. 1. Single Bell and Hopper at a Charcoal Iron Furnace — Distributing Charge in a Ring Next to the Lining.

either alone, or with a portion of coke, was used as fuel. The defect of the single bell seems to be that it does not permit, beyond very narrow limits, such changes in charging as may be required by the temporary condition of the furnace.

Modern furnaces using Connellsville or other good coke and Lake Superior ores seem to be well served with a single bell. At

* Read at the Lake Superior meeting of the American Institute of Mining Engineers, September, 1904.

least up to a certain size, somewhere about 18 by 85 feet to 19 by 90 feet, they make low silicon pig iron with about 1,800 pounds of fuel, or in some cases very much less.

The following instances occur to me, in which other forms of charging apparatus have been employed with advantage:

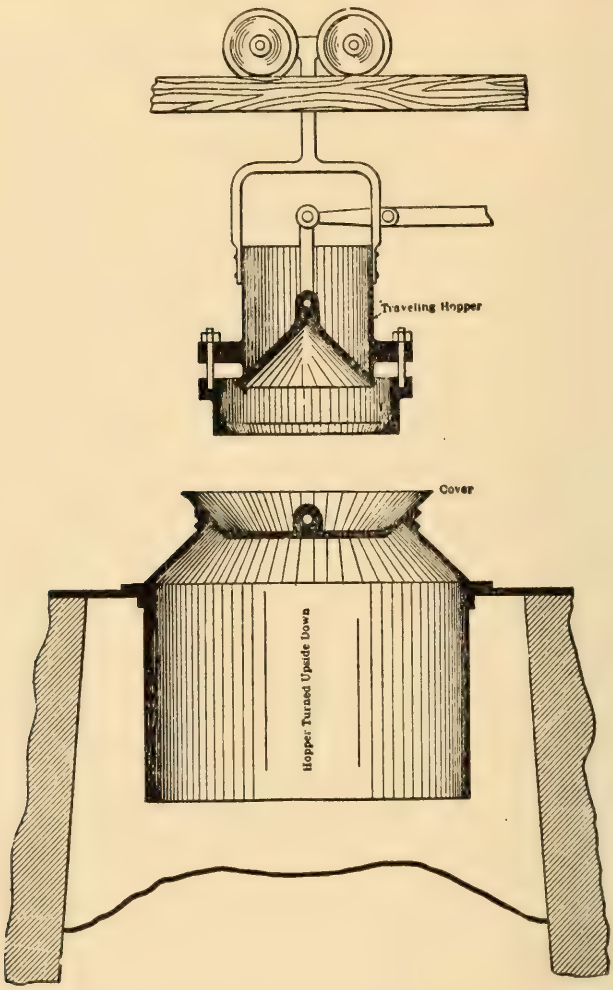


Fig. 2. Later form of Single Bell and Hopper at a Charcoal Iron Furnace — Distributing Charge in a Heap at Center.

1. A charcoal furnace, 61 feet high, 11 feet in diameter at bosh, and 8 feet 2 inches at stock line, with a rectangular crucible, 42 by 36 inches in size, and bell and hopper as shown in Fig. 1, yielded at the start black scouring cinder and white iron, and so continued for 30 days, when it was shoveled out. The gas circulation had been wholly through the center; and for 30 feet above the tuyères no fire or heat had reached the walls, the red color of

the fireclay still showing in the firebrick joints. It is probable that the small crucible, only 36 inches wide, had something to do with the center circulation. This feature was unavoidable, since the old stone stack would not permit a larger hearth.

To remedy this trouble, the charging apparatus shown in Fig. 2 was designed. This deposited all the ore and stone in a heap about three feet in diameter in the middle of the furnace. The result was favorable, except that at intervals of about eight or ten days scouring cinder and no iron would be made for two or three (in one instance for six) hours, after which regular work would begin again. That trouble was cured by increasing each fuel charge from 20 bushels of charcoal to 100 of charcoal and 25 of wood.

The fuel consumption averaged for considerable periods less than 1,600 pounds, and even for long campaigns 2,000 pounds of fuel per ton of 2,300 pounds of iron, considering that such work was done with Champlain magnetites and iron pipe stoves, more than 30 years ago, according to the practice and knowledge of that period, we must admit that the results were at least fairly good, and proved such a system of charging to be not incompatible with fuel economy.

Fig. 3. Single Bell and Hopper at an Anthracite Iron Furnace — Distributing Charge in a Ring Next to the Lining.

This apparatus was only a makeshift; but so satisfactory was its working that it was used for about five years (until the charcoal supply became exhausted), during which time the furnace worked smoothly without a single slip.

2. A second instance of unsatisfactory working with a single bell was at an anthracite furnace 71 feet high, 16 feet in diameter

at bosh, 14.5 feet at stock line, and 8 feet in the crucible, with six four-inch tuyères, and a 7.5 feet bell as shown in Fig. 3. Notwithstanding the relatively large stock line diameter, the bell banked the ore snugly against the furnace lining.

A good blow in was effected, but at the end of three months the furnace got into a scrape and the campaign was finally (though, as subsequent experience demonstrated, unnecessarily) abandoned. Examination showed a hole 55 feet deep, burned through the center, leaving about 4 feet of loose stock on the walls. The furnace could have been saved by filling the hole with anthracite, and applying an extra volume of blast.

Subsequent campaigns, so long as anthracite only was used, showed a tendency to center circulation, although the stock line

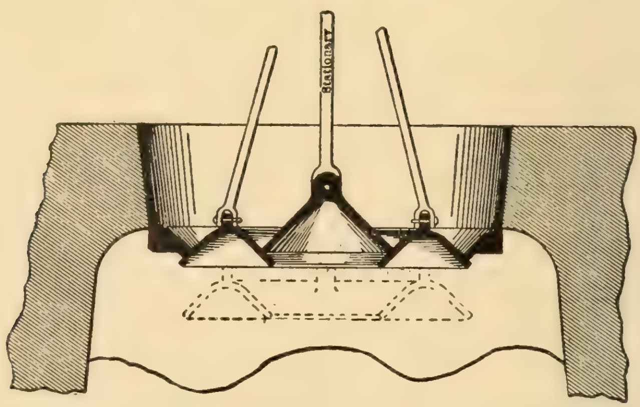


Fig. 4. The Bauman Bell and Hopper — Distributing Charge Both in a Ring Next to the Lining and in a Heap at the Center.

diameter was reduced to 12 feet. Indeed, why should this not be the case, especially when dense, heavy, fine magnetite is charged? The natural effect of a single bell, at least under the conditions above stated, is to render the outside ring of materials more impervious to the ascending gases than the center, because only the large pieces of fuel and stone roll to the center, while the ore stays about where it falls.

This tendency to burn up through the middle was, however, very much reduced by using coke as a part of the fuel. The more rapid working thus effected may have been the secret of this improvement in results.

Later, the single bell was replaced with the Bauman bell shown in Fig. 4, and afterwards Firmstone's modification of the Bauman (see Fig. 5) was added. This improved design was used

a long time, and therefore, presumably, with satisfactory results at Glendon, Pa.

3. Fig. 6 represents the Durham bell, the invention of Mr. Edward Cooper, who made many interesting experiments with it. In this design the hopper on the annular bell gives control of the distribution. This was, I believe, the first device

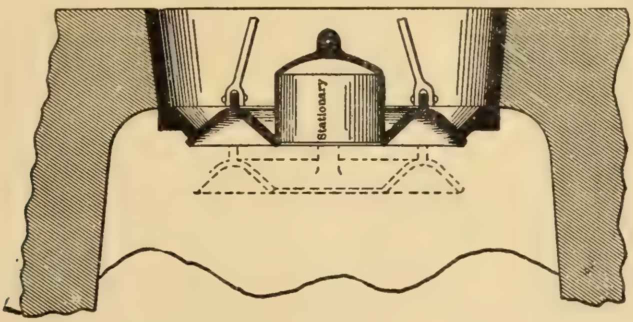


Fig. 5. Firmstone's Modification of the Bauman Bell and Hopper — Distributing Charge Both in a Ring Next to the Lining and in a Heap at the Center.

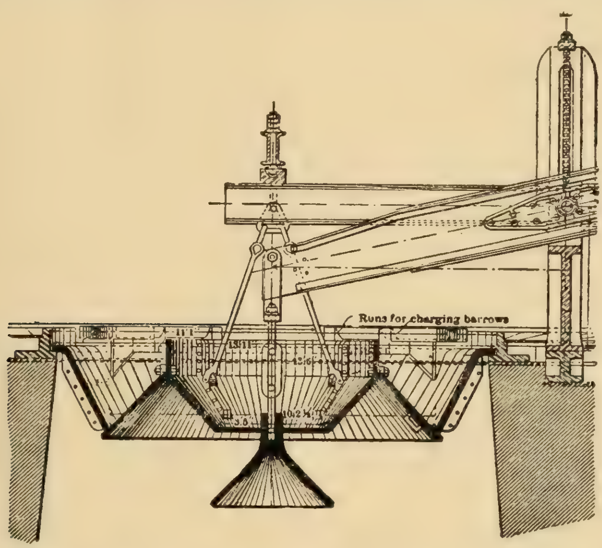


Fig. 6. The Durham Bell and Hopper — Distributing Charge in Three Ways: 1. In a Large Ring Next to the Furnace Lining. 2. In a Small Ring 3. In Both a Large and a Small Ring.

which embodied that important feature; and for this and other valuable contributions to technical progress (notably the Durham iron stove) Edward Cooper deserves the hearty thanks of American ironmasters, especially because he has always generously placed the results of his study and ingenuity at the disposal of his professional colleagues, never seeking to hinder the free use of them by protecting them with patents.

4. A charging apparatus used at Longdale furnace, Virginia, is shown in Fig. 7. It is practically a Bauman-Firmstone, with provision for taking the gas off in the center — a feature which has been highly commended.

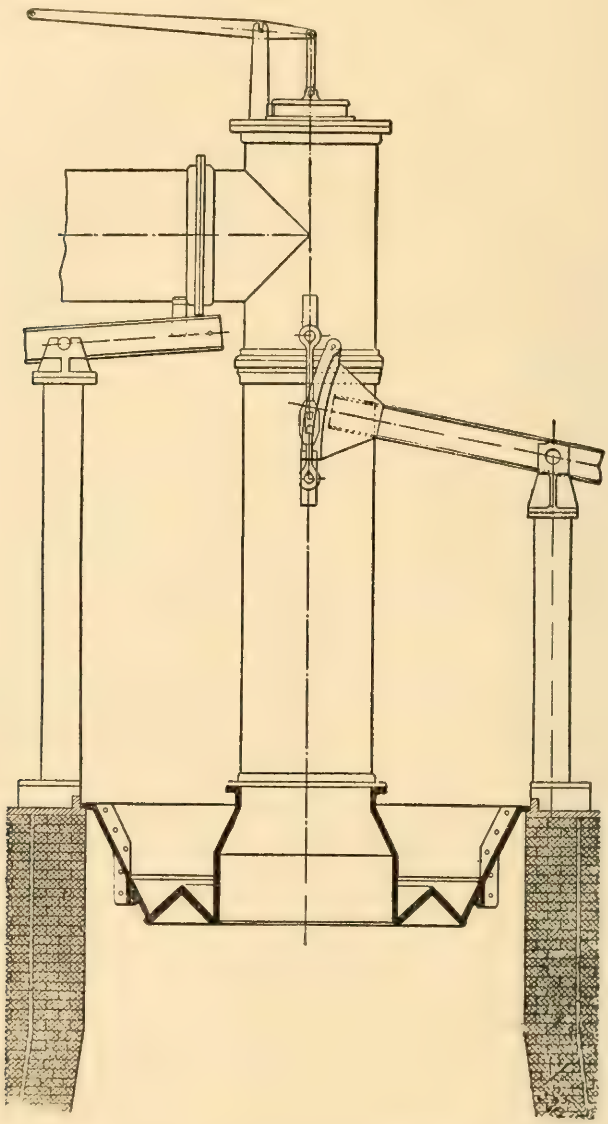


Fig. 7. The Bauman-Firmstone Bell and Hopper at the Longdale Furnace Va.— Distributing Charge Both in a Ring Next to the Lining and in a Central Heap Smaller Than That Shown in Fig. 8.

5. The double bell of the Bauman type, shown in Fig. 8, has been used by the Saucon Iron Co., New Jersey. It will be noticed that the Bauman bell deposits the ore in an annular ring and also in a heap in the center, while the Durham bell deposits

it in a large or small annular ring, or both, according as the inner or outer hopper is used.

6. In 1887 I designed the bell shown in Fig. 9, which, by means of the suspended spreader-bell, can be used to effect the same distribution as the Bauman or Durham, according as the "spreader" may be turned up or down.

This apparatus was intended to meet special conditions, particularly the coming use of Champlain magnetic concentrates, which were then as fine as Mesabi ores, besides having a higher specific gravity, and being, therefore, more inclined to run. It was under my charge for only five months, during which the furnace worked normally, and the special efficiency of the apparatus was only negatively demonstrated. As an experiment, however, the furnace was charged for about a week wholly through the inner hopper, with spreader raised, all the stock being thus put in a heap in the center. Normal work continued; but the lining came up three inches, demonstrating, what I had expected, that by means of this apparatus the ascending gases could be diverted and controlled at will.

Mr. N. M. Langdon, a member of the institute, completed the blast with this charger; and when I saw it next, after my return from Mexico in 1888, it was lying on the stock house floor, badly burned and warped (probably in blowing out), and had been replaced with a single bell. Mr. Langdon told me that he had discovered no particular difference between it and a single (which, perhaps, was commendation enough); but I am still of the opinion that the Bauman, the Durham, and the combination of the two as shown in Fig. 9, have some merit, at least for special cases. Some may consider them complicated as compared with a single bell, but in practice they are not so, since one valve controls their manipulation.

It is currently reported that the modern large furnaces (from 90 feet up) have not proved very satisfactory, so far as regularity of working and fuel economy is concerned. In the West, several have been blown out, after a few weeks' run, for decapitation and other changes; and the manager of one of the largest groups of furnaces in the United States predicted that the two which his company had under construction would not surpass the stacks 85 by 18 feet in size, except in quantity of product. The performance of these furnaces has more than confirmed his judgment, since

they have never consumed less than 2,000 pounds of fuel per ton of iron. It seems incredible that an addition of a foot or two to bosh diameter, and 15 or 20 feet to height, should be attended with such unsatisfactory results as are reported. One of my correspondents attributes this experience to a "wandering" of the blast — which is very possible, since the conditions for such a wandering are provided by the (from one point of view) excessive tuyère area.

At an anthracite furnace, with blast heated to about 1,400° F., the tuyère pipes were, of course, generally bright red; but it was noted occasionally that only two or three of the six tuyères were so, the others being black, showing that nearly all the blast was passing through the red hot ones. By partially closing the valves in the tuyère stocks of the hotter ones, the others could be reddened, and the blast, thereby, more evenly distributed.

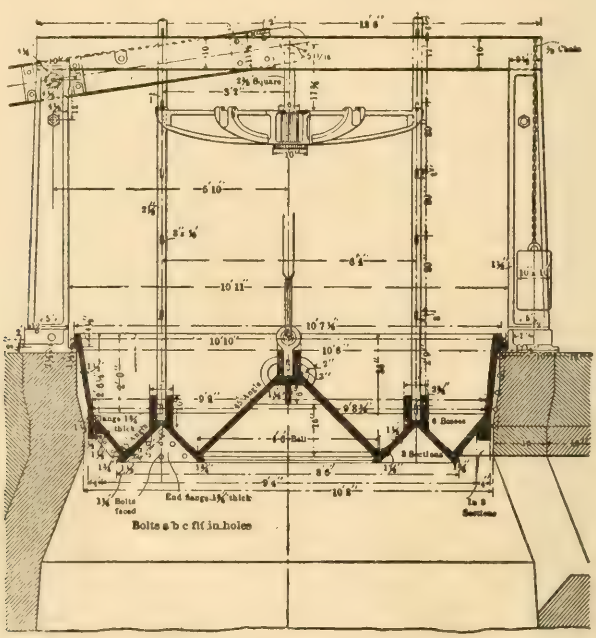


Fig. 8. Bauman Double Bell and Hopper at the Saucon Furnace, New Jersey — Distributing Charge Both in a Ring Next to the Lining and in a Heap at the Center.

Subsequently, a direct experiment showed that the volume of blast which was entering the furnace through 75 square inches of total tuyère area, would pass out into the open air through 30 square inches at the same pressure, proving that the resistance was in the stock, and not in the tuyère. Probably this condition

exists approximately at all blast-furnaces. Many years ago, Mr. John M. Hartman invented a device to show at a glance the distribution of the blast. As I remember it, it throttled the blast at each tuyère stock, thus maintaining a slightly higher

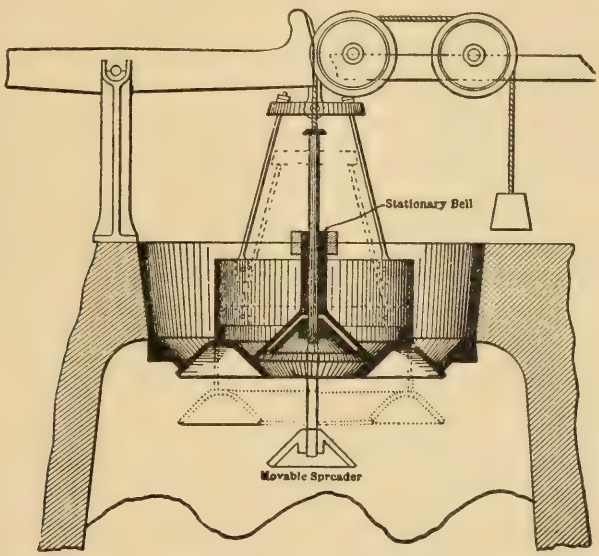


Fig. 9. The Witherbee Double Bell and Hopper — Five Ways of Distributing Charge — With Spreader Bell up: 1. A Ring Next to Lining. 2. A center Heap. 3. A Ring Next to Lining and a Center Heap. With Spreader Bell Down: 4. A Large and a Small Ring. 5. A Small Ring.

pressure in the bustle windpipe than in the furnace, so that a blast pressure gauge, applied to each tuyère below the throttling diaphragm, would show the pressure in each tuyère. If it was equal to the bustle pipe pressure, it indicated an obstruction in the zone of that particular tuyère.

While it is easy to demonstrate blast wandering, the remedy is not so apparent. Maintaining a considerably higher pressure in the bustle pipe may tend to remedy the evil, but so long as the method of charging keeps the center relatively more open, it will not be practicable to reduce the tuyère area; for, in such a case, the open center would be burned out, and the most serious of all blast-furnace derangements, a ring scaffold, would be set up, with its accompanying dust throwing, slips and so called explosions.

Perhaps any defects in working, which may have been shown by the "Jumbo" furnaces, are due, not to the size of the stacks, but to the way in which the materials, including the blast, have been distributed. If their reported fuel consumption could be

brought down to the best records of the smaller furnaces, it would represent a saving of over $100,000 per annum for each furnace — a sum of sufficient importance to justify the slightly increased complication of the charging apparatus.

It will be a surprise if the monster Buffalo furnaces do not even surpass this fuel economy, not on account of any extra superheated blast that may be at their command, but by reason of their improved charging apparatus, which, to my mind, shows a step in the right direction.

It is to be understood that whatever reference has been made to large furnaces applies to a few specific cases, reported to me, which may not be typical ones. Moreover, in these cases, fuel economy may have been sacrificed for quantity of product, as is sometimes intentionally done for good commercial reasons.

The main purpose of this paper is to present the suggestion that better results in running might be had by charging nearer to the center, so as to have a more resistant column of materials there to blow against, thereby enabling the reduction of the tuyère area enough to minimize blast wandering and its train of evils. As the matter now stands, we are obliged to use, with large bells, tuyères from 50 to 60 per cent too large, and thus practically to surrender all control of the blast at the bustle pipe, from which it can enter the furnace through any tuyères offering a relatively smaller resistance.

OBSERVATIONS ON CAST IRON*

By J. E. JOHNSON, Jr.
Longsdale, Virginia

MR. WEST has observed that plates cast from direct metal of a certain composition could be planed, whereas this would have been impracticable with cupola metal of like composition; that furnace metal has more "life" (i.e., fluidity, or a higher temperature) than cupola metal; that it throws out much "kish," etc. And he suggests that blast-furnace managers may throw further light on the greater softness of direct metal castings.

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* Prepared for the Atlantic City meeting of the American Institute of Mining Engineers.

Perhaps such light may be furnished to some extent by the present paper.

The difference between cupola metal and furnace or direct metal is, first of all, in the lower average sulphur content of the latter. It has been proved by experiment that iron increases in its content of sulphur to a considerable extent with each remelting. More than thirty years ago Fairbairn showed that a certain iron after remelting 18 times had only five-eighths of its initial tensile strength and stood one-third of its original deflection, though there had been a decided increase in both up to the twelfth remelting. He did not show the cause of these results, but they undoubtedly were due jointly to increase in the content of sulphur and combined carbon.

It is easy to calculate that, if iron be remelted with a coke containing a normal quantity of sulphur, say one per cent, with a melting ratio of ten to one, and if only half of the sulphur goes into the iron, the increase in the sulphur content of the latter will be 0.05 per cent, which, according to the usual specifications, is the maximum amount the iron is permitted to contain, as it comes from the furnace.

The reasons for the higher heat of the furnace metal are: first, that the ascending current of gases has a much lower temperature in the cupola than in the furnace because of the use of cold blast in the former. (This might be overcome in practice by the use of an excessive quantity of fuel, but it would require more than would be commonly supposed;) and second, and more important, that in the cupola the iron is exposed to the hot gases for a much shorter period, and is consequently unable to approach as closely to the temperature of the gases as it does in the furnace, to say nothing of the temperature being lower in the former than in the latter. Mr. West's experience in making workable castings from furnace metal of a silicon content which if present in iron cast from the cupola would put machining out of the question, and his contention that the hotter the metal is poured, the softer the casting, may best be considered together, as they are so closely related.

The experience mentioned can be confirmed without doubt or hesitation. It is, and has been for years, the practice of the works with which I am connected to make, for repairs, as well as for new construction, all castings within the reach of their

molding facilities, directly from a furnace producing "basic" iron, with the silicon guaranteed under one per cent and the sulphur under 0.05 per cent. The iron would perhaps average, the year round, sulphur 0.03 and silicon 0.7 per cent; and yet there are comparatively few days in the year when the ordinary run of castings may not be made without fear of their being too hard to be machined. Of course, when the furnace produces white iron showing white clear through the pigs (which are cast in chills), it is necessary for the foundry to work on castings which do not require to be machined. On the other hand, should the iron contain much above 0.9 per cent of silicon, difficulty is experienced in preventing holes and soft places in the castings, caused by the deposition of graphite or "kish" during or after pouring. "Kish" may be defined as consisting of loose particles of graphite, either thrown off into the air, or gathered on or near the surface of castings in aggregates so dense as wholly or largely to exclude the iron. In this paper, the term graphite, as distinguished from kish, means the particles more or less regularly disseminated and completely enclosed in the iron. In substance, apart from their mode of occurrence, the two are of course identical.

The best way to mitigate or prevent this trouble, which is sometimes very annoying, is to pour the iron very hot when making pieces of small or moderate size. The effect is to chill the metal from a high heat by contact with the cold mold and reduce it to the solid form as quickly as possible, thus preventing, to a great extent, the formation of graphite while the iron is molten, which gives rise to the kishy places. The graphite formed after solidification is distributed more or less uniformly throughout the metal; whereas, if the metal is allowed to cool to some extent before pouring, graphite begins to form within it, and separates out at eddies and high points of the mold, with objectionable results.

It is impossible to discuss this subject satisfactorily without making use of the well-established fact that cast iron being a member of the same series as steel, the principal effects in it are due, as in steel, to the quantity of combined carbon it contains. If the graphite, which is merely enmeshed in the cast iron, were absent, the latter would be, in fact, an impure steel, containing in general more silicon and (excepting Bessemer pig) more phos-

phorus than ordinary steel. This view was urged by me at some length in a paper published about four years ago, and was soon after expounded by Prof. Howe in such a way as to leave no room whatever for doubt.

The acceptance of this view renders available for the study of cast iron an enormous amount of material gathered from both practical and theoretical sources through many years, for the solution of problems presented by steel, in fact the work done upon steel furnishes a solid foundation for the study of cast iron. This, indeed, seems quite the natural order, since it proceeds from the simpler to the more complex compound.

A chart of the "freezing-point curves" of the iron carbon system, such as those of Backhais-Roozeboom and Roberts-Austen, shows that, with a pure cast iron containing more than about 4.3 per cent carbon, there is a range of temperature within which carbon must separate out in the form of graphite before solidification takes place; this range of temperature being closely proportional to the excess of carbon above the quantity mentioned, roughly 100° F. for each 0.5 per cent carbon.

If, then, we had to deal with a pure iron containing, say, five per cent of carbon, it is obvious that carbon in considerable quantity would have to separate out of the iron during cooling in the molten condition, and, naturally, that some of it would pass off into the air, especially in the ordinary operation of casting from a furnace, in which the running of the metal affords every opportunity for the liberation of this graphite. But, as there is little or no iron made containing five per cent of carbon, this explanation alone is insufficient.

The diagram of freezing-point curves referred to shows that with all pure cast irons the separation of graphite continues for several hundred degrees below the point of solidification; and it has been proved by direct experiment that silicon exercises a powerful influence in assisting or compelling the formation of graphite in this temperature range (a fact also well known in practice); also that it lowers very markedly the temperature at which the separation of graphite can begin, and reduces the quantity of combined carbon with which the iron can be "in equilibrium." That this action of silicon on the formation of graphite persists above the point of solidification is proved clearly by its action in relation to suddenly-cooled or chilled castings.

It is well known that in the presence of more than 1.5 per cent of silicon it is impossible to obtain any chilling action, and that, other things being equal, the strength of this action is inversely proportional to the quantity of silicon present below that amount.

So much being established, it may be taken as certain that silicon has the same effect in lowering the temperature and the percentage of combined carbon at which the cast iron is in equilibrium above, as well as below, the point of solidification. It thus lowers the percentage of carbon above which graphite is forced to separate out from the still molten iron, and this accounts for the observed fact that, at a furnace running on foundry iron, the cast-house is often full of kish, while at a furnace running on low silicon iron this is seldom seen, though the carbon content of the iron is as high (or higher) in the second case as in the first, and the iron may show a beautiful gray fracture when slowly cooled.

Many interesting facts have been developed as a result of using iron the composition of which is at the extreme limit permissible for foundry work. Castings are sometimes made from iron, of which it is known that the machining will be, at best, barely practicable; yet it is necessary to save them if possible. For such cases a very slow cooling has proved efficacious; the castings are buried in hot sand and kept there over night, or even for a whole day, if they are large, and able to hold their heat for this length of time. Of course, the slow cooling is practically identical with the annealing of tool steel, with the additional condition of the separation of graphite.

The reason for the absence of kish in ordinary cupola foundry work is that the metal, having a temperature considerably lower than that of furnace metal, has to pass, in cooling, through a much smaller part of that range above the melting point, within which graphite is compelled to separate out. Consequently, there is little or no formation of graphite during the melted state, and hence no kish. This fact does not prevent the iron from being very graphitic when cold, because, as shown by the freezing point curve, the separation of graphite continues for several hundred degrees below the temperature of solidification. It may be added that for each kind of cast iron there is a maximum of carbon which it can contain dissolved when it "sets," though much of this carbon subsequently passes into graphite in the solid state.

Any excess above this limit will be expelled in the form of graphite while the iron is still liquid. This maximum represents, in fact, the eutectic of iron and carbon for that kind of cast iron. The limit of carbon for pure cast iron is 4.3 per cent, as already stated, and diminishes with progressive increase of silicon.

If, for convenience, iron containing more than this amount of carbon be called supercarbonized, or (adopting the scientific term) "hyper-eutectic," and any increase in temperature above the melting point of the eutectic be called "superfusion," it may be said that "kish" is formed when a supercarbonized or hyper-eutectic iron is superfused.

It may be said that kish is formed by molten iron, while graphite is formed by solidified iron, and it must be noted that kish can be formed only when the quantity of silicon present is sufficient to cause the carbon dissolved in the iron to supercarbonize it, or constitute a hyper-eutectic solution. Thus, when first-class basic iron is cast in sand, it may have a most beautiful face and fracture which would cause it to be graded as No. 2 X; yet no kish will be seen flying in the cast-house. It is impossible to emphasize too strongly the influence of time in all these matters. This is well understood with regard to steel, but seems never to have been thoroughly realized with regard to cast iron, in which most of the changes common to steel occur, as well as those incident to the formation of graphite. The diagrams of freezing-point curves before mentioned, which show the cooling-curves and the internal changes of steel, are always based on the condition of slow cooling, therefore do not directly represent the effects of quick cooling.

The effect of quick cooling is to transfer a condition represented in such a diagram by the initial temperature to the lower point on the same ordinate which corresponds to the final temperature of the quick cooling, thus introducing conditions which diagram does not completely represent, especially if further cooling, at a slow rate, takes place.

Such a diagram, therefore, does not directly exhibit the results of the chilling effect of the mold on hot-poured metal. Yet it does show plainly that denying the time required for the separation of kish from the superheated metal increases the carbon content of the iron at solidification. This seems to me to indicate, further, that quick cooling raises the temperature of solidification,

and consequently increases the range, both of temperature and time, during which graphite is formed after solidification. Hence a hot-poured iron tends to be less kishy and more graphitic than if poured at a lower temperature.

These conclusions are confirmed by practice. Hot-pouring to prevent the formation of kish has been mentioned already. It may be added that, of castings made from some kinds of furnace iron, those first poured from the ladle are entirely free from kish, while those poured last from the same ladleful are so kishy as to be objectionable.

So far as I know, these general facts and their fundamental relation to the accepted theory of the general subject have not been published hitherto. It is worthy of note, in this connection, that hot-pouring tends to prevent the production of hard castings from relatively hard iron, and of kishy castings from relatively soft and kishy iron. This may explain the strong insistence of foundrymen upon "hot" iron. Concerning the formation of graphite it must not be forgotten that, as Professor Howe has pointed out, the important question is not how much graphite is formed, but how much combined carbon is left.

Observations of irons habitually low in both silicon and sulphur content make much plainer the action of the latter element than do those of irons further removed from the chilling point by the presence of more silicon; and it seems to me, as a result of several thousand such observations, that the harmful effects of sulphur have never been properly emphasized. So far as I know, a lower sulphur content than 0.05 per cent is seldom or never specified in foundry or other standard varieties of iron, and yet an iron with 0.05 per cent sulphur is no more to be compared with a similar iron containing 0.025 per cent sulphur than coke-made white iron is to be compared with cold-blast charcoal iron.

At the works above mentioned, as at many others, it is the custom to take from every cast a small chill-cast sample (roughly 1.25 inches by two inches in cross-section by seven inches in length), remove it from the chill-box when it has cooled to a dull red, quench it as quickly as possible and break it. When the furnace is running on basic iron of standard composition, these chill samples will show from the faintest line of white at the lower corners, with one per cent silicon and, say, 0.02 per

cent sulphur to dead white with lower silicon and higher sulphur. Through a very large part of the range of analysis covering the best basic irons low in both sulphur and silicon, these samples are solid white and their variations in fracture, according to the sulphur present, are astonishingly great to be covered by the single title "white." It is not necessary to go into a detailed description of these variations here. I will only say that the low-sulphur irons have a beautiful bright, very markedly crystalline structure (the crystals being long slim pyramids with their bases against the sides and bottom of the chilled surface and pointing toward the center), while the higher-sulphur irons have a structure increasingly flat and non-crystalline; and while the general surface of the fracture with low-sulphur irons is always approximately a plane perpendicular to the length of the sample, this is decreasingly so with higher sulphur, the fracture eventually becoming almost conchoidal. At what are considered very moderate sulphurs for foundry iron, beginning about from 0.05 to 0.06 per cent with low-silicon iron, the sample becomes cracked in cooling, and at 0.075 per cent sulphur, will frequently fall into many pieces at the lightest tap when cold, though, it should be said, this latter condition is apparently more marked at some times than at others, even though the irons contain identical quantities of sulphur, silicon and other elements, ordinarily determined.

That sulphur, however, is the principal cause of these variations of physical properties is sufficiently proved by the fact that with experience it becomes perfectly possible to estimate the sulphur in the iron by the fracture of its chill-samples, and as a general thing, to come within 0.01 per cent of the laboratory determination.

With iron approaching one per cent silicon the effects of sulphur are to some extent masked, but not completely. Its effect in reducing the size of the grain, increasing the depth of chill and blackening the color of the gray part of the fracture is plainly apparent.

That sulphur has an effect in producing a chill (throwing the carbon into the combined form), precisely opposite to that of silicon, is shown very clearly by a study of the chill-samples, but this is so generally understood that there is no need to elaborate it here; though it cannot be too plainly stated that silicon is not on that account a complete neutralizer of sulphur.

The exact internal effects of sulphur in steel have been clearly shown by Prof. Arnold and Mr. J. E. Stead, and there is little or no reason to doubt that the action is the same in cast iron. It may be well to recall here that this action, briefly, is to form a very fusible iron sulphide which remains liquid long after the rest of the iron has solidified, and disseminates itself between the grains of the iron, thus severing or weakening their continuity. It is not to be expected that silicon, for which sulphur has little affinity, should neutralize such an influence, whatever its effect may be in opposing that of sulphur on carbon. This point is of much importance practically, for the reason that much foundry practice at the present time seems to be founded on the belief that silicon is a neutralizer of sulphur.

Since the quantity of sulphur in iron increases considerably at each melting, it is natural that scrap which has had at least one remelting will contain a higher percentage of sulphur, and therefore will have a more marked tendency to chill, than furnace iron; and as high-silicon iron will undoubtedly soften white iron, it is perhaps natural to assume that the addition of the former is all that is necessary to soften scrap. Undoubtedly such an addition will counteract, wholly or in part, the chilling tendency; but it does not follow that this remedy will neutralize all the other effects of sulphur. When it is remembered, moreover, that the action of silicon in preventing the formation of combined carbon is certainly completed at, if not below, two per cent, the wisdom of using mixtures which contain more silicon than this limit as they come from the cupola is open to question, especially as silicon is a hardener on its own account, and beyond this percentage a weakener also. Silicon, when present in greater quantities than two per cent, is also a great dirt-producer in castings. This matter of dirt-production does not receive much attention in general; but I feel confident that many sand-holes in castings are due to silica, produced by the combustion of silicon in the cupola, and remaining suspended in the metal until the latter comes to rest in the mold, and gives a chance for the silica to separate.

The cleanness of castings made from low-silicon furnace metal, as compared with those from ordinary cupola iron, would surprise those who have not witnessed the difference.

Just how far silicon neutralizes the evil effects of sulphur

is one of the most important questions of foundry practice to-day, and should without doubt be investigated by some one able and competent to do it; preferably under the auspices of some engineering society. I recently outlined what I believed to be a satisfactory method of investigation, and I hope that something in this direction will be accomplished before long.

Not much can be done to remedy high sulphur in the iron after it has passed through the cupola. The addition of manganese in some form in the ladle is the only method which has been tried to any extent; and it has yielded good results in some cases, though its use is open to various objections of a practical kind, such as the high cost of ferro-manganese, which is practically the only form of manganese available for the purpose; chilling of the iron in the ladle, if the ferro-manganese is charged cold; or the cost of pre-heating it, if it is charged hot. Nevertheless, there are many cases in which it could be profitably used, care being taken not to add too great an excess, and thereby increase the percentage of manganese in the iron to a point where hardness would result.*

So far as I know, calcium carbide has never been used for this purpose; but it is well worthy of a trial. It compares favorably with ferro-manganese in cost, while its combining power and its affinity for sulphur are much greater; moreover, it is an endothermic compound, and therefore its decomposition would impart heat to the metal. Moreover, calcium, being a powerful deoxidizing agent, would tend to remove any oxygen present in the form of iron oxide. The possibility of the presence of iron oxide in a highly carbonized metal like cast iron is strongly denied by some; but I am more and more convinced that it is present in white iron.

Much can be done, however, to prevent the absorption of sulphur by the iron in the cupola. The first step is, of course, to use iron and coke low in sulphur, the next is to use an iron containing considerable manganese, say from 0.75 to 1.5 per

* Since this was written, I have heard of a method, developed in Germany, for removing sulphur by adding manganese ore to the charge. This absorbs the sulphur and slags it off, very much as if the manganese were in the metallic state, but at less expense. I have no exact details of the process and its results; but it is said to have been successfully used in Germany.

cent since this quantity slags off the sulphur and prevents it from entering the iron. In the running of the cupola much can be done by slagging it freely, and there does not seem to be any reason why additions of lime should not be made in such quantity as to neutralize the extreme acidity of the slag. If from one to two pounds of limestone were charged for every pound of silica in the coke-ash, the slag would be very fusible as compared with blast-furnace slags, but enormously more powerful in the removal of sulphur than one without lime. In a ten-ton heat with a melting ratio of ten to one and coke containing seven per cent silica, there would be 140 pounds of silica in the charge, and 200 pounds of lime added to this would have a marked effect in reducing the sulphur-content of the resultant iron if at all excessive, at an utterly insignificant cost. A still more calcareous slag would be inadvisable, under the present conditions of cupola practice, because, with the cold blast used, a sufficient temperature would not be attained to melt it. But this brings up the question: Why are no cupolas blown with warm blast?

A calculation of the quantities of heat required and expended in melting iron, or an examination of the top of a cupola in operation, will show that there is plenty of available heat, which could be utilized to save fuel. It has been calculated that from 25 to 40 per cent in fuel consumption could be saved by heating the blast; and this would permit the use of relatively calcareous slags which would reduce the sulphur content and give better iron — results opposite to those obtained in general practice, when any attempt to economize in fuel is made with cold blast.

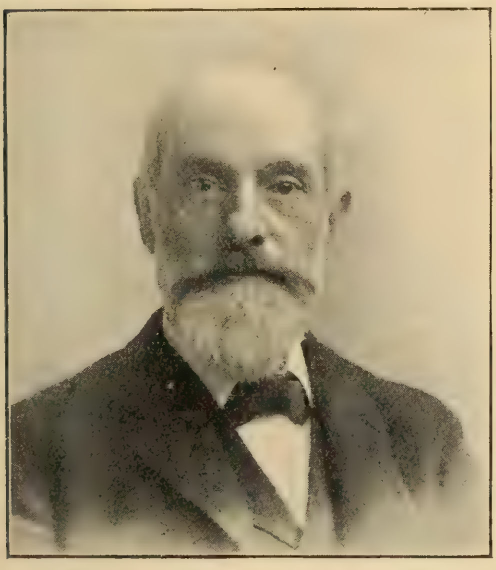
The means of heating the blast could be very simple, merely some wrought or cast iron pipes located in an enlargement of the cupola stack and connected by return bends, with external joints out of reach of the fire. The quantity of air admitted at the charging door would give a simple means of controlling the temperature and thus avoid any damage to the pipes. The blast would pass through the pipes in series on its way to the windbox, and could probably be heated as hot as desired without difficulty and without excessive cost for repairs. The pipes would be exposed to no danger of being burnt up when there was no air passing through them, because at such times the cupola would not be going to any extent worthy of consideration.

Many other phenomena concerning this interesting subject have come under my observation, but as these concern the production of cast iron (furnace practice) rather than its use, they are omitted from the present paper.

THE MANUFACTURE OF STEEL*

By WILLIAM METCALF

THIS article is a comparison of the production of steel in the United States in the years 1892 and 1902, showing advances in the decade in capacity, quantity and quality.



It was the intention, originally, to take the years 1893 and 1903, but the year 1893 was one of phenomenal depression and 1903 one of remarkable activity, so that a comparison of them would hardly give a fair average of progress; besides, the statistics for 1903 are not compiled completely and are not available at the time of writing.

The statistics given are the work of Mr. James M. Swank, General Manager of the American Iron and Steel Association, whose distinction and world-wide reputation are a sufficient guaranty of accuracy and completeness.

Capacity

The sizes of Bessemer converters and open-hearth furnaces, in gross tons, were as follows:

In 1892 there were converters of 3, 5, 7, 10, 15 and 20 tons in use.

In 1892 there were in use open-hearth furnaces of from 5 to 35 tons.

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* Read at the International Engineering Congress, St. Louis, Mo., October 3 to 8, 1904.

In 1901 there was no increase in size of converters.

In 1901 there were many open hearths of 50 tons and one of 75 tons.

The sizes in use in 1902 are not published, but it is fair to assume that there was little change from 1901.

TABLE NO. 1 — *Total Annual Capacity*

	1892	1901
Bessemer	6,560,000 net tons	12,938,000 gross tons
Bessemer-Clapp-Griffith	170,000 net tons	....
Open-Hearth	1,550,000 net tons	8,289,750 gross tons
Crucible	105,000 net tons	175,000 gross tons
Totals	8,385,000 net tons	21,402,750 gross tons
Or	7,486,607 gross tons	

TABLE NO. 2 — *The Production of All Kinds of Steel Ingots and Castings, in Gross Tons*

	1892	1902	Increase in 10 years
Bessemer	4,168,435	9,138,363	4,969,928
Open-Hearth	669,889	5,687,729	5,017,840
Crucible	84,709	112,772	28,063
Miscellaneous	4,584	8,386	3,838
Totals	4,927,581	14,947,250	10,019,669

It will be observed that, while the output of Bessemer steel was about doubled, the increase of open-hearth was more than eightfold, and crucible steel increased only one-third; the quantity of miscellaneous being comparatively insignificant.

The estimated world's production of steel is given as 10,948,000 in 1889, and 30,680,000 tons in 1901. Judging by these figures, Table No. 2 indicates that the United States is keeping up with the world's progress.

Having given the figures of quantity, showing a large increase, the question naturally arises, what of quality?

In the finest grades of crucible tool steel, there has been no improvement in quality in the last 40 years. Manufacturers 40 years ago were making steel that has never been improved, but prices were excessively high, so that the uses were limited; ordinary grades were selling as high as from 14 to 16 cents per pound.

The introduction and development of the manufacture of tool steel in the United States aroused the attention of iron manufacturers to the possible field that was opening, and they followed it up, with the result that now the same quality of steel is sold at six cents per pound, or even lower, and the quality, if anything, has been improved; leaving only the very finest grades not improved upon, and not reduced much in price. These remarks apply strictly to carbon steels. There has been a marked development in the production and use of alloy steels, which will be discussed later.

In Bessemer steel, and in open-hearth steel especially, there have been marked improvements. The enormous development of open-hearth steel has undoubtedly limited the application of Bessemer steel to fewer purposes than would otherwise have been the case, but there can be little doubt that this competition has kept Bessemer steel makers up near to the highest attainable limit of uniformity and quality.

In open-hearth practice, there has been a great improvement in handling large heats, so as to produce much more uniform steel than the practice of ten years ago permitted. This is more marked in the higher steels, which are the most difficult to make.

The low steels most commonly in use, not higher than from 0.20 to 0.30 carbon, were made always with satisfactory uniformity, but the demand for higher carbons led to a great deal of trouble. To illustrate: In order to overcome serious objections to car springs, specifications were made fixing an allowable maximum of P, S, Mn and Si, and limiting carbon between 0.90 and 1.10.

The use of this steel led to an immediate and marked improvement in the quality of springs, so great that the specifications were adhered to and have become standard. The P, S, Mn and Si apparently gave no trouble, but the carbon limits were so hard to attain in 30 to 50-ton furnaces that some of the ablest and most successful steel makers, after repeated trials, said frankly that they could not do it, and the making of this material was relegated to small furnaces of from five to ten tons capacity. To-day, the same steel is made in 50-ton furnaces with satisfactory regularity; that is to say, if the mean of a heat is 1.00 carbon, it will rarely run as low as 0.90 or as high as 1.10 in any part of the heat, and this result proves to be entirely satisfactory in practice.

Table No. 3 gives a list of variations which manufacturers are willing to guarantee.

TABLE NO. 3

Carbon desired	Limit guaranteed	Carbon desired	Limit guaranteed
0.10	0.08 to 0.12	0.60	0.52½ to 0.67½
0.20	0.15 to 0.25	0.70	0.62½ to 0.77½
0.30	0.25 to 0.35	0.80	0.70 to 0.90
0.40	0.35 to 0.45	0.90	0.80 to 1.00
0.50	0.42½ to 0.57½	1.00	0.90 to 1.10

This degree of uniformity has proved to be entirely satisfactory in practice, and this is one of the chief reasons for the great increase in the output of open-hearth steel, and the very small increase in the quantity of crucible steel.

For many purposes, where crucible steel was used formerly, and sparingly on account of cost, open-hearth steel is used now with entire satisfaction, and in great quantities because of its comparative cheapness and excellent quality.

Up to this time no open-hearth steel has been made which will take the place of crucible steel for fine lathe work, complicated tools such as milling cutters, etc., heavy, high-speed cutting and the finer engraved dies; but while it seems to be hardly possible to reduce the cost of crucible steel to where it can compete with open-hearth steel, it is always possible that the quality of open-hearth steel may be improved so as to meet the best that the crucible can produce, and the next generation may learn to look on the crucible process as one of the abandoned arts.

HEAT TREATMENT

Much has been made of late of the matter of heat treatment of steel, due chiefly to the persistent statements of metallographers of the marked effects on structure of comparatively minute differences in temperature and treatment, and, owing to the vital importance of the subject, it is well that some person has at last aroused the attention of engineers. As a matter of fact, it is no new thing. Experienced steel makers have understood it all along, and from time to time they have called attention to it, apparently to little purpose.

Any man who is fit to manage a mill knows very well the

importance of proper heat treatment and is pretty sure to use it in his own interest, if not always in the interest of his customer.

One illustration may be interesting: A large heat of spring steel is made to specification; it contains:

Carbon	between 0.90 and 1.10
Phosphorus	<0.05
Sulphur	<0.05
Manganese	<0.50
Silicon	<0.20

It conforms to the specification, and is furnished in sound, beautifully-rolled bars, and is accepted. In the hands of the spring makers it is so red-short that it breaks in pieces and cannot be used.

Clearly, the red-shortness was not due to sulphur or any other recognized impurity; equally clearly, the mill men understood heat treatment thoroughly and the spring makers did not.

In the making of steel, aside from the use of proper material, the one vital, all-important matter is the melting. Steel is made or marred in the melting furnace; given the best material in the world, if it is not melted properly, it will not make the best steel, and it is just here where skill and care pay well and cost nothing; for, given the good material, it costs no more to bring it out the best steel, than it does to blunder over it and bring it out poor stuff.

The skilled heat manipulators may make it look well, but no amount of after skill will make a lot of badly melted steel as good as it should be or as it would have been if melted properly.

These remarks apply to the crucible as well as to the open-hearth steel.

In regard to science as applied to steel making, there appears to have been little improvement in chemistry except as it may apply to celerity and accuracy in the laboratory; it does not seem that any advance has been made in determining the quantities of oxygen, hydrogen and nitrogen in steel, or their effects. It is certain that they are present, and, especially as concerns oxygen, harmful; this is evident in the red-short heat to which reference has been made.

Metallographers have made many and minute investigations of the structure of steel by the microscope and pyrometer; they have shown the remarkable sensitiveness of steel to heat variations,

confirming all the statements of mill metallographers and manufacturers, which have been published from time to time for many years; proving once more that when correct and accurate observations are made, the operations on the large scale and the investigations in the laboratory will agree. This far their work is valuable and to be commended. That it will lead to any extended use of the microscope and pyrometer in the mills is doubtful, for the following reasons:

There may be a variation of several hundred degrees in temperature in any furnace. In what part of the furnace shall a pyrometer be applied to determine the temperature?

There may be a difference of 1,000° in the temperature of different parts of the same bar. At what part of such a bar shall a pyrometer be applied?

Again, a furnace may be of fairly even temperature of the desired amount, with a flame that is simply cutting away the steel instead of heating it. How can a pyrometer give any indication of such a state of affairs?

In all these cases a properly skilled heater, or manager either, can determine these matters at a glance, and with absolute certainty.

A piece of steel may have been heated very badly, either too hot, too cold, or, worse still, very unevenly; the microscope will give the structure of various spots of the size of a pin head, involving much labor and time in the operations. A skilled, experienced steel worker can see the whole condition by a glance at a fresh fracture.

Nature has supplied the best pyrometer and microscope combined, in the trained eye, governed by good sense and sound judgment, and it is doubtful if, for good work, these natural faculties will ever be improved upon by any instruments of man's devising.

Alloy Steels

Alloy steels may be defined as steels containing metals other than iron, which produce marked effects. Air-hardening or self-hardening steel, nickel steel, and Hadfield's manganese steel are well known, and we have no record of any special changes or advances in the decade, except that new uses are being found for them, and may lead to considerable development.

High-speed steel is the one remarkable, revolutionary de-

velopment of the decade. In the necessary heat treatment, it reverses nearly all the best practice for carbon steel; and in its work it has practically revolutionized the machine business of the world. As far as it is developed at present, it consists usually of medium carbon, generally under 0.80, very little manganese, from 10 to 20 per cent of tungsten or molybdenum, and, generally, from three to four per cent of chromium, although some brands do not contain chromium. It is hardened by heating almost to fusion and quenching in an air-blast or in cold oil.

It will make heavy cuts at a remarkably high speed for metal working, hence its name, causing a temperature that will blue steel chips and that would ruin instantly any carbon steel tool.

To predict what may be the final outcome might lead to the idea that one had let his imagination run wild; certainly the results are already startling. So many brands are upon trial, and so many diverse claims are made, so much has been written and will be written on the subject, and there is still so much that is doubtful and uncertain, that it seems as if this were not the time nor the place for any further discussion. That had better be left to those who are directly interested and who will doubtless make themselves heard.

THE FRACTURE OF STRUCTURAL STEEL UNDER ALTERNATING STRESSES*

By JOHN OLIVER ARNOLD

Professor of Metallurgy, Sheffield University College

THE efforts of steel metallurgists and engineers to obtain scientific control over the mechanical properties of steel used for structural engineering purposes, although attended with much success, have nevertheless presented certain unfortunate features of failure. Thirty or forty years ago it was claimed, apparently with reason, that if the chemical constituents of mild steels were identical, their mechanical properties were necessarily similar. But, as experience extended, it soon became evident that steels registering practically the same chemical analyses gave astoundingly different mechanical tests. The next stage of research led to the enunciation of the generally-accepted idea that steels having

* British Association, Section G.

a good chemical composition, correlated with satisfactory tensile and bending tests, were thoroughly reliable. But the advent of high speeds placed engine parts under rapidly alternating tensile and compression stresses, the reversals being, in some instances, at the rate of 800 per minute. Under these new conditions, the sense of security ensured by a good chemical composition and satisfactory static tests was rudely disturbed by the fact that steel, in a relatively small number of cases, was liable to fracture far below its elastic limit, more after the manner of glass than of a ductile metal.

These facts led to a remarkable development of the micrographic method of examining steel. The results obtained have thrown considerable light upon the matter; but after 15 years' correlative research, the inexorable logic of facts compels the author to state with regret that in connection with this particular matter the microscope in its turn has to a considerable extent broken down in its attempt to solve that mystery of steel, of all others the most important practically, namely, the cause and prevention of its sudden rupture under vibration and alternation, two phenomena probably closely allied. The author here wishes to emphasize and reiterate the fact that he is discussing steels possessing great toughness and ductility under ordinary static tests.

To pass from generalities: The author, through the kindness of his friend, Mr. J. T. Milton, Chief Engineer of Lloyd's, is enabled to publish, with a certain degree of reserve, important facts ascertained during a two years' research carried out with the assistance of his friend and colleague, Mr. Andrew McWilliam, A. R. S. M., at the University College of Sheffield, under instructions from Lloyd's Committee.

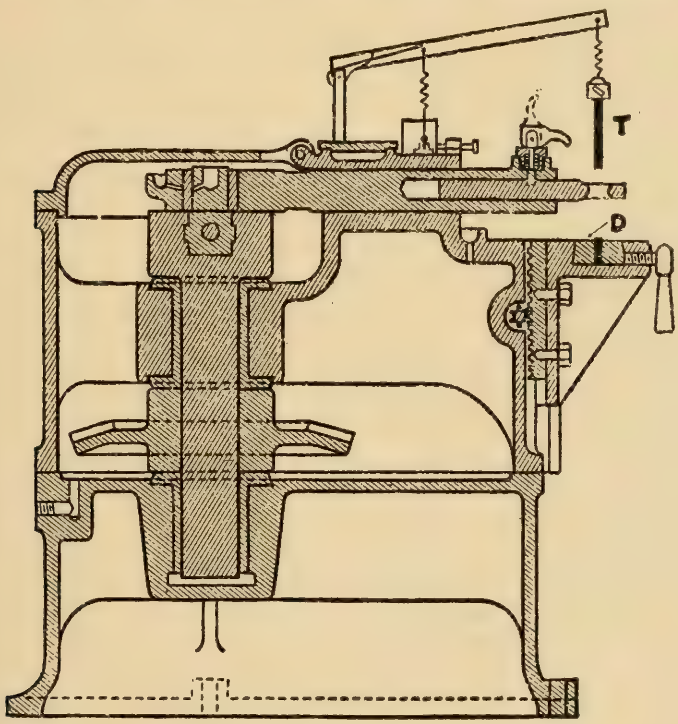
To select one instance: the shell-plates of the boiler of a colonial cruiser split longitudinally from end to end, under the hydraulic test. The fractured plates were about one inch thick, and each weighed nearly three tons. The average analysis of the plates was about as follows:

Carbon	0.20
Silicon	0.02
Manganese	0.50
Phosphorus	0.04
Sulphur	0.04
Copper, Arsenic	Very low

Of course the above analysis is beyond reproach. Pieces from the fractured plate, bent double and closed right up under violent hammering, without any sign of flaws. The average tensile tests registered about:

Elastic limit	15 tons per square inch
Maximum stress	29 tons per square inch
Elongation	29 per cent on two inches
Reduction of area..................	50 per cent

The above mechanical tests leave little to be desired. The microscopical structure showed a distinct and unusually sharp



Professor Arnold's Testing Machine.

segregation of the pearlite and ferrite, the latter being angular and intensely crystallized. It was also large in pattern, and frequently occurred in those long white lines, rich in sulphur and phosphorus, which are technically known as "ghosts."

In the early stages of the research it was thought that the sharp crystallization might be regarded as an effect due to that cause which produced also the effect of brittleness. As will be seen presently, this theory was decisively negatived by subsequent experiments. In order to measure the mechanical brittleness in-

capable of being detected by ordinary static or bending tests, the author caused to be devised the machine represented in the full-sized diagram exhibited.

The test piece T is along the line of the die D rapidly placed under severe alternating stresses, slightly beyond its elastic limit, produced by the rotation of an eccentric on the vertical shaft of the bevel wheel, but the strain along this line is necessarily relatively small. The number of alternations are registered by a counter, adjusted to zero for each test. The rate of alternation can be varied at will, and in the near future these data will be supplemented by a record of the energy expended per test piece, ascertained by means of a delicate integrating Watt meter. This method of testing — which practically carries out the almost impracticable Wohler test in one or two minutes — has already thrown important light on the obscure phenomena under investigation, and has also exhibited remarkable delicacy. These facts are proved by the data now submitted to the section by the author.

In preliminary tests on standard English acid open-hearth boiler plate steel the remarkable fact was noted that in all probability the resistance of structural steel to rupture under rapidly alternating stresses is inversely proportional to the rate of alternation. This law, if fully established by the exhaustive experiments now being carried out at the Sheffield College, demands careful attention from every engine designer. The following figures indicate concretely the data upon which the author provisionally enunciates the law. The subjoined table has reference to alternating shock bending tests carried out on a good boiler plate steel, the test bars being three-eighths of an inch square and the bending force being applied four inches from the line of maximum stress, with a range of nine-sixteenths of an inch each side:

Mark	Rate of alternation per minute	Number of alternations necessary to complete fracture	Mean
S 1	168	1,330	
S 2	168	1,456	
S 3	168	1,352	1,375
S 4	168	1,361	
S 5	266	860	
S 6	266	870	
S 7	266	916	878
S 8	266	868	

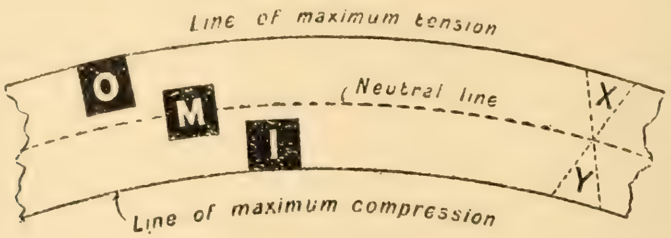
Whilst the above results exhibit considerable concordance, those obtained from the fractured boiler plate were so erratic that for a time the author was almost in despair, when the curious clue to the situation presented itself, that one side of the plate was brittle and the other tough under alternating stresses. This theory is about to be put to a most careful experimental test, but in the meantime the following data are, in all probability, substantially accurate:

Mark	Rate of alternation per min.	No. of alternations endured	Heat treatment	Probable position of test-piece
L 3	169	420	Heated to 950° C. and cooled in air	Inside
L 4	169	1232		Outside
L 7	169	1378	Oil quenched from 950° C.	Outside
L 8	169	694		Inside
L 11	266	433	As received	Inside
L 12	266	864		Outside
L 18	266	260	Heated to 950° C. and cooled in air	Inside
L 19	266	500		Outside
L 20	266	388	Annealed; heated to 950° C.; slowly cooled	Inside
L 21	266	781		Outside
L 22	266	630	Oil quenched from 950° C.	Outside
L 23	266	240		Inside
L 26	266	400	Water quenched from 900° C. Heated to 600° C.	Doubtful
L 27	266	336		Doubtful

The somewhat disconcerting lessons to be drawn from the above table are: (1) That once a steel has assumed decisive brittleness in alternation, it cannot be restored by heat treatment of any kind short of remelting; (2) that the injury to this steel was on one side of the plate, and hence due to unskilful reheating of the ingot and not to an improper casting temperature, since the latter must necessarily have affected every portion of the plate. A third and still more regrettable confession has also to be made, namely, that the micro-structures of the pairs, including both brittle and tough steel, were in all respects identical, though, of course, that of each pair varied with the heat treatment to which they had been subjected.

The author wishes finally to record some delicate and interesting tests obtained from an inch plate of mild steel bent over a radius considerably shorter than that of a large boiler, namely, about two feet. In such a plate the inside radius will represent a

line of maximum compression stress, the outside radius a line of maximum tensile stress, and a radius exactly between the two will touch a neutral line. See accompanying figure.



If, from the apices of two V's, X Y, progressing inwards and outwards, lines are drawn to the inner and outer circumferences, these V figures will qualitatively represent the increasing intensity of the stresses at increasing distances from the neutral line. As to the quantitative value of these angles, the author has no practical data. The following table records the influence of stress in deteriorating the metal next the inner and outer radii, and also that immediately adjacent to the neutral line.

Mark and position	Rate of alternation per minute	Number of alternations endured	Remarks
O..............	266	916	Mean of ten tests
I..............	266	996	Mean of ten tests
M.............	266	1,067	Mean of ten tests

It will be seen that in its resistance to fracture under alternating stresses, the portion of the plate in tension is inferior to that in compression, whilst the steel about the neutral line is superior to that next the inner radius.

All the results recorded in this paper are preliminary, having been carried out on an extemporised machine. A standard machine has now been erected at the Sheffield College, from which the author hopes to obtain, in the near future, standard data as to the influence of sizes and shapes of test pieces, length of stroke, rate of alternation, and the correlation, if any, between the data and the energy necessary to produce fracture.

INITIAL STRESS IN STEEL*

LAST week we dealt at some length with the controversy between Professor Arnold and Mr. Stead regarding the results of heating steel.† It will be remembered that a large marine boiler supplied test pieces to Professor Arnold which left nothing to be desired; but the boiler itself "cracked like glass" under the stress of the hydraulic test. We are now enabled by the courtesy of Mr. J. Milton, chief engineer surveyor to Lloyd's, to give some additional information concerning the boiler. The plates were about an inch thick, and the boiler was of the ordinary Scotch type, with three furnaces. There was one circumferential seam, double riveted. There were longitudinal butt joints, also double riveted. Standing in front of the boiler the fracture was on the right-hand side, a couple of feet above the longitudinal seam. Apparently it started at a rivet hole in the middle of its length and ran both ways. It stopped at a rivet hole at the front end circumferential seam, and the other end terminated where one of the combustion chamber stays was screwed into the shell. In the middle of its length the crack was open a good half inch, and both plates were cambered out slightly. There are several noteworthy points about the failure. The most remarkable is that the fracture ran through two distinct plates. In a word, it is a boiler fracture, not a single plate fracture. We can imagine one plate to be bad and crack, but why should both plates crack as if they were one? The material appears to have been about 30 tons steel. The test pressure would stress it to, say, 10 or 11 tons; perhaps two tons under the elastic limit. It is quite clear that within the conditions there must have been an initial stress existing somehow and somewhere in the plates. If there was no such stress the plates would not have failed. It also seems that this initial stress must have amounted to something like 20 tons per square inch. The added ten tons of the hydraulic test just sufficed to cause the failure. Did this initial stress exist in both plates? If so, how did it get there? The crack started, as we have said, at a mid-length rivet hole. Did one plate go first, and the other then give way under the additional stress so thrown on it? Why is it that no stretching or contraction

* "The Engineer."

† See page 442 of the present issue of *The Iron and Steel Magazine.*

of area took place at the crack? These and various other questions await answers.

We have already said that the failure of the boiler has no bearing whatever on the vibration theory of detrioration, or on Wohler's law. The interest all centers in the fact that test pieces cut from the plate satisfied every conditions of a first-rate boiler steel. It is true that Professor Arnold says that he found that small pieces of the plate tested in his machine were not improved by heat treatment, and that the two sides of the plate were not the same. But this has very little bearing on the facts of the rupture of the boiler. Neither Professor Arnold nor anyone else can prove that the steel on the worst side of the plate was not good enough. There is no evidence whatever that the cracks began in the bad side. In a word, although Professor Arnold's investigation was in one sense highly instructive, it leaves us not in any way better informed as to the reason why the boiler plate failed, which happens to be the real question of interest to engineers. There is enough information available, however, acquired from this and some similar cases, to enable us to arrive at an explanation of the reason why boiler plate tests which satisfied all reasonable conditions were deceptive and misleading. The reason may be stated in a very few words. It lies, indeed, in a nutshell. No matter what the initial stresses in a large plate, none exist in small pieces cut off that plate for the purpose of test. Because a strip two inches wide and one inch thick requires a pull of 60 tons to break it, we must not assume that a plate five feet wide and one inch thick will not break under a stress of less than 1,800 tons. But it is on an assumption of this order that all deductions from tests are based. Because a small test piece withstands a certain pulling effort, we jump to the conclusion that a large plate or bar of the same material will act in the same way. The deductions would only be justifiable if we were sure that there were no initial stresses at all in the plate or forging. As luck will have it, this is true in the great majority of cases. It is not true now and then, and so we hear of the so-called mysterious failure of a boiler plate, or a connecting-rod, or a piston-rod. If we could only get behind the scenes, and see what is going on within the plates or the bars, we should probably say that the real mystery lay in the circumstances that a plate or a bar had been able to stand any stress whatever, not that it broke.

The disquieting fact is that even dangerous initial stresses may exist in any considerable mass of steel, be it a plate or a bar. To what are the stresses due? So far as can be seen, to unequal contraction, the result of irregular cooling. Let us, for example, suppose that on the floor of a plate mill a plate hot from the rolls, some five feet wide and 15 feet long, is suffered to lie. It begins to cool; in a few minutes a second and much smaller plate, also hot from the rolls, is laid on the first. Now, the outlying portion of the large plate will cool, while the middle is kept at a high temperature by the second plate. After a time the middle area cools; but when it attempts to contract it finds the outer portion already rigid. It is true that it, too, has contracted somewhat, but not enough, and the result is that the inner portion of the plate must remain in tension after it has cooled. Very little then will suffice to cause fracture. In some such way as this the cracking of the boiler plates under the hydraulic test may be explained; and we also see what great benefit would arise from Mr. Stead's system of heat treatment. The uniform re-heating and cooling of the plate would relieve it of initial stresses, just the result most desirable; but it is quite evident, we think, that the relaxation which might be brought about in this way would not make a strip from the plate, no matter where it was cut, behave either better or worse in Professor Arnold's testing machine; simply because small pieces, being without initial stress, required no relaxation.

If steel plates and bars never gave way apparently without any good reason, the whole subject would possess only an academic interest. It is quite true that "accidents" of the kind are rare, but they do occur, and that more frequently than is commonly supposed. Very often the failure is detected — as, say, in a crank shaft — before mischief is done. Few or many, it is beyond doubt that engineers are very easily rendered uneasy about steel, and that those in responsible positions are not quite content with the present position of affairs. For ourselves, we hold that there is really little or no cause for alarm; but none the less it is necessary that great care should be taken to secure the equable and steady cooling of all large plates and masses of steel. The rate of cooling does not appear to make much difference so long as the temperature is the same at any moment in every part of the plate. The latter would no doubt be the better for annealing

in a furnace. The ideal method of cooling boiler plates, and one by no means impracticable, would result in raising them on edge and slinging them in the air. The plant required would be inexpensive and the room occupied small. The simplest plan would be to drop the plate edgeways through the mill floor into a cell below, analogous in a way to a soaking pit, except that means could be used to convey away the heat. The manufacture of steel has now reached a very high degree of excellence. Its peculiarities are fairly well understood. Engineers know something about the difference between Bessemer basic and Bessemer acid steels, and those from the Siemens-Martin or open-hearth furnace. The great object to be attained now by the steel maker is the exculsion of the initial stresses. No one can do so much as he can. But we think that he has hardly yet realized the supreme importance of the conditions, or the necessity for providing for the perfectly equable cooling of the output of the rolling mill.

STEEL*

IT is not easy to read Professor Arnold's British Association paper,† published in our pages last week, without consternation. Its author tells us in fairly plain terms not only that there is a mystery about steel, but that all existing methods of research cannot solve it. Thirty or forty years ago the engineers were assured that so long as the chemical constitution of two steels was the same, their properties would be identical. This theory is the foundation on which hundreds of specifications have been drawn up. It has influenced the process of manufacture and the value of ores more than any other conceivable conditions; yet, as Professor Arnold told his hearers, not much time passed before steel began to give the lie to the assertions of those who had made its structure and behavior a life study. Then came an addition to the theory which, in a way, wrecked it. If the percentages of silicon, sulphur, carbon, phosphorus and manganese were correct, and the steel would stand bending and tensile stresses and tests, then it was good steel. To these asertions

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* "The Engineer," September 9, 1904.

† See page 439 of the present issue of *The Iron and Steel Magazine*.

the steel makers not inconsistently made answer that the chemical qualities appeared to be of so little importance that the only thing necessary was the mechanical test. The metallurgical chemist asserted that unless the constituents of the metal were right it could not possess the requisite ductility and high elastic limit. Therefore, when a steel came out of the testing house with a high record the chemist ought to admit that sufficient proof had been supplied that the carbon, phosphorus, etc., percentages were what they should be. This seems reasonable; yet it has never been accepted as sound logic, and so the war between steel makers and engineers goes on merrily. Recently new ground has been broken — the aid of the microscope has been called in. For the theoretical metallurgist, steel may be said to have disappeared, and its place has been taken by pure iron, modified, mixed, and controlled with and by such substances, or various conditions of the same substance, as martensite, sorbite, pearlite, austenite, and so on. Faith in the microscope became extensive and profound; and now comes Professor Arnold to tell the world that on one most important part of the steel question, after 15 years of research, "the inexorable logic of facts has compelled me to state with regret that in its turn the microscope has to a considerable extent broken down in its attempt to solve that mystery of steel of all others the most important practically — namely, the cause and prevention of its sudden rupture under vibration and alternation, two phenomena probably closely allied."

Our readers will do well to follow Professor Arnold's arguments very closely. In few words, he contends that a steel piston-rod, let us say, made of apparently the best materials that can be got, is liable at any moment to fracture, because it is submitted day after day to alternating stresses of tension and compression. He says that a steel of great toughness and strength in the testing machine, and no doubt competent to withstand very high static loads, may break like glass when the loads are dynamic; and he adds that the chances of fracture vary with the rapidity of the alternations, and in the duration and character of the stresses. We commend to our readers' attention the figures given by Professor Arnold, and published on page 227 of our last issue. This is sufficiently startling, but it is not all. It will be remembered that at the Düsseldorf meeting of the Iron and Steel Institute held two years ago Mr. Stead asserted in the most positive language,

that steel which had been deteriorated by vibratory and other dynamic stresses could be quite restored by raising it to a good red heat, pulling it out of the fire, and letting it lie on the ground till it cooled. No annealing was necessary. That, in a word, it is the heating, not the cooling, that restores the original good qualities of the metal. But Professor Arnold's paper contains the following words which refer to two specimens of steel, particulars of the test of which he gave: "The somewhat disconcerting lessons to be drawn are that once a steel has assumed decisive brittleness in alternation, it cannot be restored by heat treatment of any kind short of remelting; and a regrettable confession has also to be made, namely, that the micro-structures of the pairs, including both brittle and tough steel, were in all respects identical, though, of course, that of each pair varied with the heat treatment to which they had been subjected."

The contradiction between the two men is flat. Nevertheless, out of the dust and turmoil of battle comes the fact that each states the conclusion at which he has arrived from experiment. It is in this that we find the greatest reason for alarm. Two most careful and competent men arrive at directly opposite conclusions on a question of the highest importance to engineers. That such a result is possible appears to us to confirm in the strongest possible way the truth of the proposition that we are all as far from understanding steel as we were thirty years ago. A connecting-rod in a high-speed engine is supposed to be developing brittleness as the result of the multiplication of alternating stresses. Mr. Stead says to the engineer, "Heat the rod to a bright red, let it cool, and it will be as good as it was at the first." Professor Arnold says, "You will merely waste your time if you do anything of the kind. If mischief has been wrought, it is irreparable."

Let us now go a little below the surface, and see on what grounds Professor Arnold has based conclusions so startling. In January of the present year the Report of the Alloys Research Committee of the Institution of Mechanical Engineers was presented, and it was followed by a very animated, not to say acrimonious, discussion, in the course of which Professor Arnold criticised Mr. Stead with a good deal of energy, saying, among other things, that Mr. Stead had discovered nothing, as the restoration of steel by heating it to 1,600° F. or so, and then letting it cool on the floor, had been practiced under the name of "faking"

as far back as 1820 in Sheffield by Charles Wardlaw. He then went on to speak of the boiler plate sent him by Mr. Milton. The same plate is referred to in his British Association paper. It is very easy to fall into a slight error here. Be it remembered that Professor Arnold was dealing at Cambridge with Wohler's law. Now the boiler plate had not been submitted to any dynamic stress whatever. It had been bent, drilled, and riveted into the shell in the normal way. It was a plate which had stood every test, chemical and mechanical, and yet when the boiler was submitted to hydraulic pressure "it split from end to end like glass." Here we have a phenomenon of intense interest; but it has nothing whatever to do with Wohler's law or any other law that is known. Professor Arnold told the members of the institution that "the steel on analysis was all right, the elongation was all right, the reduction of area was all right. It was subjected to the most severe bending tests. It was hammered violently close up. It was bent close up in the testing machine without showing a flaw. According to all precedent, it was a steel of splendid quality, with faultless chemical analysis and mechanical test; but the fact remained that the boiler went like a piece of glass." The story carries us back to the old days, when a big Atlantic liner lay in dock in Liverpool, and boys sent in to chip the flues fled in alarm, and it was found that three of the furnaces had cracked from end to end with terrifying reports. Specimens from Mr. Milton's plate were tested, as briefly described, at Cambridge, and at far greater length in London. At first sight, however, it is quite difficult to trace any connection between the cracking of the boiler plate and its failure under Wohler tests. In fact, there is no real connection whatever. We are just as far, after reading Professor Arnold, from guessing why the boiler plate cracked as we were before. It is true, indeed, that he showed by his experiments that each side of the plate behaved differently; but why he does not attempt to say — for the present at least. All that the experiment served to do was make it clear that the two sides of the plate were not the same. The tests were intended to measure mechanical brittleness that could not be detected by ordinary static or bending tests. But the results obtained, although they are suggestive as regards piston-rods, for example, are, we submit, useless as regards boilers.

The reason why Mr. Milton's plate cracked must, we hold,

be sought in a different direction. The phrase used by Professor Arnold, " split like glass," is suggestive. It is not impossible that a fine hair crack of the right kind was developed during the construction of the boiler, and that under the test the crack ran as cracks will run. We are not aware of the existence of any microscopic research as to the nature of cracks. We have a sound end of a plate, say of glass, and a cracked end. Just where the crack meets with the sound portion is the crucial point, and we fancy that very strange and interesting information as to the molecular arrangement and action and interaction would result from an inquiry into the whole subject; such an inquiry is, however, surrounded with difficulties of observation, and for this reason, perhaps, it has not been taken up.

Returning to Professor Arnold and Mr. Stead, we earnestly hope that the first-named gentleman will pursue his inquiry with energy and despatch. Nothing can be more unsatisfactory than the uncertainty existing as to the results of the heat treatment of steel. If Professor Arnold is right, then quantities of connecting-rods, piston-rods, and such like, ought to go to the scrap heap at once. If, on the other hand, Mr. Stead be right, they can at a very small cost be made as good as they ever were. Possibly, however, steel will take care that questions of this kind can never be settled. It has an unfortunate way of being all things to all men, which is, to say the least, confusing.

MODERN METHODS OF MAKING IRON AND STEEL*

Pennsylvania's Part in Their Introduction

SUCCESSFUL experiments in the use of coke in the blast-furnace in this country date from 1835, when William Firmstone, a native of England, succeeded in making good forge pig iron for a month at the end of a blast at Mary Ann furnace in Huntingdon county, Pennsylvania, with coke made from Broad Top coal. This pig iron was taken to a forge three miles distant and made into blooms. Coke had previously been used in a small

* J. M. Swank in " The Bulletin of the Iron and Steel Associations," September 10, 1904.

way in forges in Pennsylvania and as a mixture with charcoal in a few blast-furnaces. About 1837 F. H. Oliphant made at Fairchance furnace, near Uniontown, in Fayette county, Pennsylvania, a quantity of coke pig iron exceeding 20 tons, and probably exceeding 100 tons. He did not, however, long continue the use of coke and resumed the manufacture of iron with charcoal.

The first continuous use of coke in the blast furnace in this country was accomplished at Lonaconing furnace, at Lonaconing, in Western Maryland, in 1838 or 1839. In June, 1839, this furnace, which was built by the George's Creek Company, was making about 70 tons per week of good foundry iron. Other furnaces, particularly in Western Pennsylvania, soon afterwards used coke, but its use as a furnace fuel did not come rapidly into favor and many experiments with this fuel were attended with loss. Anthracite coal was for many years after 1840 the favorite blast-furnace fuel next to charcoal. It was not until after 1850 that the use of coke began to exert an appreciable influence upon the manufacture of pig iron. In 1849 there was not one coke furnace in blast in Pennsylvania. In 1856 there were 21 furnaces in Pennsylvania, all in the Western part of the State, and three in Maryland which were using coke or were adapted to its use, and their total production in that year was 44,481 gross tons of pig iron. After 1856 the use of coke in the blast-furnace increased in Pennsylvania and was extended to other States, but it was not until 1869 that the country made more pig iron with coke than with charcoal, and not until 1875 that it made more than with anthracite. In 1902 more than nineteen-twentieths of the country's total production of pig iron was made with coke, either by itself or in combination with anthracite coal, raw bituminous coal, or charcoal. Pennsylvania produces more coke than all the other States combined.

After many unsuccessful experiments with anthracite coal in the blast-furnace, and a few moderately successful experiments, the use of this fuel in the manufacture of pig iron was made entirely successful in 1840 by David Thomas, a native of Wales, born in 1794, who, on the third day of July of that year, blew in the first of the furnaces of the Lehigh Crane Iron Company, at Catasauqua, Lehigh county, Pennsylvania, with the new fuel. Water power from the Lehigh river was used in blowing the furnace. On July fourth its first cast of pig iron was made. From the start this

furnace produced 50 tons a week of good foundry iron. Other furnaces soon began to use anthracite coal, and in a few years the manufacture of anthracite pig iron became an important branch of the iron industry of Pennsylvania and adjoining States. In 1855 the country made more pig iron with anthracite coal than with charcoal. About 1840 the use of anthracite coal in the puddling and heating furnaces of rolling mills in Eastern Pennsylvania and in some other States became general. It had previously been largely used in the generation of steam. To-day comparatively little anthracite coal is used in the blast-furnaces in this country, and the most of what is used is mixed with coke. In 1902 all the pig iron made with anthracite coal alone amounted to only 19,207 tons.

The use of raw bituminous coal, or uncoked coal, in the blast-furnace, which has never been an important factor in the manufacture of pig iron in this country, and which is now virtually abandoned, has been chiefly confined to the Shenango and Mahoning valleys in Pennsylvania and Ohio respectively, in which a particularly hard bituminous coal, known as splint coal, or block coal, is found, and which is not a good coking coal. The use of this coal in its raw state in the blast-furnace dates from 1845, when Clay furnace, in Mercer county, Pennsylvania, was successfully operated with it for some time. In the same year Mahoning furnace, in Mahoning county, Ohio, was built expressly to use this fuel. Other furnaces in the two valleys mentioned were soon built to use raw coal and some charcoal furnaces were altered to use it. In 1856 six furnaces in Pennsylvania and thirteen in Ohio were using it, their total production in that year being 25,073 gross tons. Some progress was afterwards made in the use of the same quality of coal in the Hocking valley in Ohio, and also in Clay county and neighboring counties in Indiana, but since 1880 its use has gradually declined, until to-day very little pig iron is made with this fuel, and when used it is mixed with coke.

The first shipment of iron ore from the Lake Superior region was made in 1850, and consisted of about ten tons, "which was taken away by Mr. A. L. Crawford, of Newcastle, Pennsylvania." A part of this ore was reduced to blooms and rolled into bar iron. It was hauled around the falls of Sault Ste. Marie on a strap railroad one and a quarter miles long.

The first use of Lake Superior iron ore in any blast-furnace

in this country occurred in 1853, at Sharpsville furnace, in Mercer county, Pennsylvania, then owned by David and John P. Agnew, and in the same year it was used at Clay furnace, in the same county, at both furnaces successfully. After 1856 other furnaces in Pennsylvania and in other States began the use of Lake Superior ore. The first use of Cuban iron ore was in 1884 at furnaces in Eastern Pennsylvania owned by the Bethlehem Iron Company and the Pennsylvania Steel Company, which companies had undertaken the development of the iron ore deposits of the Gem of the Antilles.

At the Siberian rolling mill of Rogers & Burchfield, at Leechburg, Armstrong county, Pennsylvania, natural gas, taken from a well 1,200 feet deep, was first used as a fuel in the puddling furnace. In the fall of 1874 it was announced that during the preceding six months this gas had furnished all the fuel required for puddling, heating, and making steam at these works. Soon after 1874 the firm of Spang, Chalfant & Co., owners of the Etna Iron Works, at Etna, in Allegheny county, Pennsylvania, introduced the use of natural gas in all departments of its works. In 1901 there were 45 iron and steel works in Allegheny county which used natural gas in whole or in part, and 28 works in other parts of Western Pennsylvania which used this fuel. In other parts of the country there were 44 works using natural gas in that year. In June, 1904, the whole number of works in the United States which used natural gas was 135, of which 54 were in Allegheny county and 33 were in other parts of Western Pennsylvania.

The manufacture of steel by the old-time method of cementation had an existence in Pennsylvania, as in some other states, before the Revolution, but it never attained a position of much prominence, while the manufacture of crucible steel, although often experimented with, and sometimes very successfully, made but slow progress down to about 1860. Up to this time the country's main reliance for steel was upon English manufacturers, who were favored in our markets by low duties. The manufacture in this country of crucible steel of the best quality may be said to have been established on a firm basis after Hussey, Wells & Co. and Park, Brother & Co., of Pittsburg, and Gregory & Co., of Jersey City, New Jersey, in the years 1860, 1862, and 1863 respectively, succeeded in making it of uniform quality as a

regular product. The event was of great importance, as it marked the establishment in this country of a new and greatly needed industry. Dr. Curtis G. Hussey, of Pittsburg, is entitled to the honor of having established this industry in our country on a solid foundation, the firm of which he was the head having successfully made crucible steel of the best quality as a regular product in 1860 for the first time in our history. Of the country's total production of crucible steel in 1902 Pennsylvania made over three-fourths, and nearly all of this large proportion was made in Allegheny county.

The manufacture of pneumatic or Bessemer steel was commenced in an experimental way in this country at Wyandotte, Michigan, in 1864, and at Troy, New York, in 1865. We waive all discussion of the conflicting claims of William Kelly, of Eddyville, Kentucky, and Sir Henry Bessemer, of England, to priority of invention of the Bessemer process, but it is important to add that the steel made at Wyandotte was made by a company which was largely composed of Pennsylvanians. In June, 1867, the Pennsylvania Steel Company, at its works at Steelton, near Harrisburg, made the first Bessemer steel that was made in Pennsylvania. In 1867 this country produced 2,679 tons of Bessemer steel and 2,277 tons of Bessemer steel rails. The first steel rails ever rolled in the United States upon order, in the way of regular business, were rolled by the Cambria Iron Company, at Johnstown, Pennsylvania, in August, 1867, from ingots made at the works of the Pennsylvania Steel Company. From this time on the manufacture of Bessemer steel in this country steadily advanced, although slowly at first, until in 1902 the country produced 9,138,363 tons of Bessemer steel and 2,935,392 tons of Bessemer steel rails. From the first Pennsylvania has been by far the most active of all the states in the development of the Bessemer steel industry. Of the country's total production of Bessemer steel ingots and castings in 1902 Pennsylvania made over 46 per cent, and of the total production of Bessemer steel rails in the same year Pennsylvania's share was 38.7 per cent.

The manufacture of steel by the Siemens-Martin, or open-hearth, process was introduced into this country in 1868 by Cooper, Hewitt & Co., at the works of the New Jersey Steel and Iron Company, at Trenton, New Jersey. For many years this method of making steel made slow progress in the United States. In August,

1875, there were 13 establishments in this country which were then making open-hearth steel or were prepared to make it, and five of these were located in Pennsylvania, of which three were in Pittsburg. The total production of open-hearth steel in 1875 was, however, only 8,080 tons, and ten years afterwards it was only 133,376 tons, but in 1895 it was 1,137,182 tons and in 1902 it was 5,687,729 tons. Of the total production in 1902 Pennsylvania's share was 4,375,364 tons, or nearly 77 per cent. The production of Allegheny county in that year was 2,503,245 tons, or 44 per cent of the whole country's production.

More than four times as much open-hearth steel is now made in this country by the basic process as by the original acid process. In a census report for 1890 we find the following statement concerning the first basic open-hearth steel made in the United States: "The first basic steel made in the United States was produced experimentally at Steelton, Pennsylvania, by the Pennsylvania Steel Company, on May 24, 1884, in a Bessemer converter. The beginning of the manufacture of basic steel in this country as a commercial product, however, dates from 1888, on the 28th of March of which year the first basic open-hearth steel was produced at the Homestead Steel Works of Carnegie, Phipps & Company Limited, at Homestead, near Pittsburg, Pennsylvania. Since that date the manufacture of basic open-hearth steel has been continued at these works." It is proper to add, however, that for about three months in 1886 basic steel was successfully made in commercial quantities in the open hearth by the Otis Iron and Steel Company, at Cleveland, Ohio.

THE SURFACE HARDENING OF STEEL*

A Study of the Processes of Cementation as Applied to Carbon Steel and to Special Steels

By LÉON GUILLET
Société des Ingénieurs Civils de France

THE process of cementation is one of the oldest in the metallurgy of iron and steel, since the original method of producing steel was that of heating iron in contact with carbon until a partial combination took place, the product being afterwards made homogeneous by remelting in crucibles. The ordinary operation of case-hardening is also a cementation process, and this, in various modified forms, is yet most important, being employed alike for the improvement of the small parts of modern automobiles, and equally for the perfection of the massive pieces of armor plate of the latest types.

In a paper recently communicated to the Société des Ingénieurs Civils de France, by M. Léon Guillet, the manner in which the operation of cementation, or surface carbonizing of steel, is effected is discussed at length, making use of the methods of metallography, or the microscopic study of the structure of the metal under various conditions.

Until recently the operation of cementation was one concerning which but little was known, from a scientific point of view, nearly all the practical work being performed according to empirical methods, acquired by experience, and often jealously guarded as valuable trade secrets. M. Guillet has shown that the process is one entirely capable of reduction to scientific and rational system, and examines its details in a most interesting and valuable manner.

The object of cementation is the production of a piece which shall be tough and resistent in the interior, while the exterior surface is given a certain degree of hardness, suitable to stand wear or abrasion, and capable of receiving a finish possessing a low coefficient of friction. In order to produce this result the article is made of mild steel and then surrounded with carbon and subjected to a temperature sufficiently high to cause the carbon

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* "The Engineering Magazine," September, 1904.

to dissolve in the iron. This gives a piece with a surface rich in carbon, while the interior remains unchanged, and a subsequent tempering permits the production of a surface of any degree of hardness desired. It thus appears that the operation of cementation is really one of dissolving carbon in a solvent of iron or mild steel.

This operation appears to be a very simple one, but investigations in the light of modern theories show it to be really very complex. Osmond has shown that iron can dissolve carbon only when the former is in what is called the *gamma* state, and that iron in either the *alpha* or *beta* states is incapable of dissolving carbon. For this reason it is necessary that the iron should be raised to a temperature of 800° C. before the operation of cementation begins. If the operation is conducted at the temperature at which the change from the *beta* to the *gamma* state begins there will be formed simply a layer of cementite, without any true solution of the carbon in the iron. The extent of the solution also depends upon the amount of carbon already contained in the steel, as well as the nature of the carbonizing material employed. In general, there are four factors to be considered in the operation: The nature of the steel; the nature of the cementing material; the temperature at which the operation is conducted, and the time during which the contact is maintained. It has been maintained by some that there are steels which are incapable of cementation, but M. Guillet maintains that this is incorrect so far as carbon steels are concerned, although it is true for certain special alloy steels.

By employing the methods of microscopic metallography M. Guillet has made some valuable studies as to the influence of variations in temperature, time, and material upon the effects produced, including the depth of the carbonizing, the time required for penetration, and the distribution of the carbon. These results are best exhibited to the eye by photography, and a number of micro-photographs are reproduced in the original paper. In general it appears that there is no variation in the time required for the penetration for steels having an original carbon content of 0.51 per cent or less, while for steels of higher carbon content rather discordant results were obtained. The time of penetration seems to depend upon the temperature, this appearing very clearly in the photographs. The influence of the cementing material is

also to be considered, but it is impossible to lay down any precise points in that respect, owing to the wide variation in materials, and it becomes necessary to determine the action of each substance by experiment.

In general the cementing materials may be divided into three classes: Those acting by the formation of carbonic oxide; those acting by means of a cyanide; and those employing hydro-carbons. Experiments made with pure carbon in a vacuum have demonstrated that no cementing action takes place; it is necessary that air be present and that carbonic oxide is formed. In the case of the cyanides there is a decomposition in which the carbon is liberated to be dissolved in the steel, while when hydro-carbons are employed, in the form of illuminating gas, petroleum vapor, etc., the carbon is released by dissociation. In general M. Guillet gives rules to be employed in practical operations. Steel of 100 to 150 carbon should be used. The cementing material should have a definite chemical composition, such as a mixture of 60 parts of carbon and 40 parts barium carbonate. The operation should be conducted at a temperature of 800° to 850° C., the temperature being maintained as nearly uniform as possible. It is desirable that there should be sufficient cementing material at all points around the piece, and a thickness of at least five centimeters of the carbonizing cement should be provided. The cemented piece should be allowed to cool and then placed in a furnace having a temperature of about 800° C., and allowed to become uniformly heated, after which it should be quenched.

M. Guillet illustrates a number of designs for furnaces to be used for cementing work, and discusses various practical points, in connection with the regulation of temperature, handling of material, and other details.

The cementation of special alloy-steels is also discussed in the paper of M. Guillet, but the extent of this field renders it impossible to do more than touch upon it. The best results have been attained with a nickel steel, containing about two per cent of nickel and 0.20 carbon. Such a steel is much more readily cemented than an ordinary carbon steel, and it should be quenched at a lower temperature, about 750° C. Data are also given concerning experiments with manganese, chrome, tungsten, and molybdenum steel, but further investigations with these are desirable.

The paper of M. Guillet, of which we have been able to give here but a brief abstract, is a most important contribution to the subject of workshop metallurgy, and it shows conclusively the manner in which rational and scientific methods may well replace the older empirical manner of conducting such important operations.

THE RESISTANCE OF METALS TO CUTTING*

Dynamometric Measurements of the Forces Involved in the Cutting of Metals in the Lathe

By DR. J. T. NICOLSON
Institution of Mechanical Engineers

SEVERAL months ago we reviewed in these columns the exhaustive experiments conducted by Dr. Nicolson at Manchester upon the performance of rapid-cutting tool steels, and now we have, in a paper presented at the Chicago meeting of the Institution of Mechanical Engineers, an interesting account of the ingenious form of lathe-tool dynamometer designed and used by him in investigating the forces acting upon a cutting tool.

The object of such an apparatus will at once appear from Dr. Nicolson's account of the conditions which led to its design:

"In the tool-steel trials made by the Manchester Committee in 1902-3 (the report upon which was published by the Manchester Association of Engineers in their Transactions for 1903), there appeared an entire lack of uniformity in the shapes and angles of the tools submitted by the eight competing firms. There was also no obvious connection between the shapes and angles of the tools and the cutting forces upon these tools deduced in the report from the electrical power measurements made by the Committee. Neither did the shape or angle supply a clue to the causes of success and failure in the various trials with different tools.

"On the other hand, the necessary reconsideration of the design of lathes for the rapid and heavy cutting rendered possible by the new steels introduced by Taylor and White, and now everywhere adopted, calls for a thorough and systematic investigation of the forces acting upon a cutting tool. If a standard area of cut can be agreed upon for the various sizes of lathe, a knowledge

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* "The Engineering Magazine," July, 1904.

of the forces to be overcome when taking that cut, — not only for turning the work against the tool, but also for moving the slide-rest and saddle in both the traversing and surfacing directions — will enable the calculation of the stresses in, and the proportioning of, the various parts of the machine to be gone about in a rational and scientific way.

"No such knowledge has hithertoo been available; and it appeared to the author that the prosecution of a somewhat extensive research into the matter would well repay the time, labor, and expense, which it would necessarily involve."

In reviewing the work of previous experimenters in this field Dr. Nicolson refers to the work of Hartig, who eununciated the law that the cutting force varies in simple proportion to the depth of the shaving; also to the investigations of Mr. Mallock, in the engineering workshop at Cambridge University. The experiments of Professor R. H. Smith are also briefly discussed, and the defective features of his apparatus pointed out. No mention is made, however, of the exhaustive researches of M. Codron upon all kinds of cutting operations, although these have been published in full in the "Bulletin de la Société d'Encouragement pour l'Industrie Nationale." The researches of Codron, however, do not include the new high-speed steels, and so are of comparative value only, although they have thrown much light upon the true nature of all metal-cutting operations.

The detailed construction of the dynamometer of Professor Nicolson is fully given in his paper. In general it consists of an attachment to the tool holder and the slide rest, composed of hydraulic supports connected to Bourdon pressure gauges. The first form of dynamometer was arranged to measure only the vertical forces acting upon the point of the tool, while the second apparatus was constructed to measure not only the vertically directed force, but also that tending to push the tool and saddle backwards, and that tending to oppose the traversing feed. The apparatus was designed to permit pressure as high as 15 tons to be observed, and pressure of ten tons were actually measured during the trials.

In conducting the tests it was necessary to assume certain trial forms and angles of tools. The first trials were made with tools having the cutting edge horizontal, and at an angle in plan of 45° with the axis of the work. The top surface of the tool was

a plane containing the cutting edge, and inclined at the angle called "the cutting angle" to the vertical plane, which also contained the cutting edge. The cutting edge terminated at a point three-eighths of an inch from the right-hand corner of the tool (in 1¼-inch square tools) so that the average cut taken would give a downward thrust, acting as nearly as could be arranged in the center line of the tool, so as to prevent any twisting action and undue load upon the steel center points. The nose of the tool had a clearance angle in plan of not less than 1°, and a small radius was ground on the corner between the two edges. The front clearance was 6°, the tools being used with the cutting edge on the level of the center of the work.

Tests were made upon case iron and upon steel with this form of tool, and also with tools set to the angles of 60°, 75°, and 90°, with feeds of one-sixteenth, one-eighth, one-quarter, and three-eighths inch, and with depths of cut of one-eighth, one-quarter, three-eighths, and one-half inch, the results being fully tabulated in the paper. Broadly, the conclusions drawn are: for a given traverse the cutting force is simply proportional to the depth of cut; the cutting stress being constant for a given width of traverse and given tool angle. The cutting stress varied widely with the cutting angle, being a minimum for an angle of about 60°, although this is not the angle of greatest durability. A cutting angle of 80° appears to be the best adapted for shop use, the cutting stress for this angle being about 75 tons per square inch. The variation of cutting stress with traverse is somewhat complicated. For keen cutting angles, below 75°, fine traverses require less cutting force than wide ones, while for blunt-nose tools the reverse is the case.

In general it appears that the ordinary shop tool, when cutting soft steel, exerts a vertical force of about 100 tons per square inch of area of cut removed, irrespective of the proportion of width of traverse to depth of cut.

"All the trials were made in the endeavor to determine the laws of the variation of *cutting force* with tool-angle and with shape of cut. It was, however, not *à priori* to be expected that the tool-angle which gave the smallest cutting force would also prove the most durable or remove the greatest weight of material before failure. As this is a point of even greater practical importance than the other, two further series of trials were pro-

jected, one on the soft steel, the other with the medium cast iron, for the purpose of finding the cutting angle to be commended for shop use.

"In the cast-iron series a cutting speed of 44 feet per minute, with a cut three-sixteenths inch deep by one-sixteenth inch traverse, was decided upon, after about 15 preliminary trials had been made. It was found in these preliminary experiments that a foot per minute, more or less, in the cutting speed made a great difference in the duration of the experiment; and, as time and material had to be economized, the careful adjustment of the speed was necessary to ensure uniform and consistent results. Cutting angles of less than 60° were excluded, but it was decided to use tools of 60°, 65°, 70°, 75°, 80°, 85° and 90° cutting angles, and to run them at the above speed *exactly* until they failed."

The results of these endurance tests showed that for maximum endurance in cutting cast iron the tool should be ground so that the true cutting angle is about 81°; or if an angle of 6° for clearance be allowed, there will be an included angle of 75°. For steel a cutting angle of about 70° or an included angle of 65° appeared to last the longest for rapid cutting.

For the details of these and a number of other tests the reader must be referred to the original paper, but these general conclusions will be of special interest. The whole investigation leads to a confirmation of the points now being generally made in modern works management, and discussed in the articles by Mr. Ashford and Mr. Day elsewhere in this issue; namely, that the choice of the form and position of the tools should not be left to the unaided judgment of the workman, but should be determined according to scientific principles and experiment, and prepared by special mechanics in the tool room, leaving the duty of the machinist at the lathe, planer, or other machine to the use of the tools which have thus been prepared for him.

The importance of the experiments of Dr. Nicolson to the designer of machine tools need not be emphasized, since it is evident that they furnish him with data hitherto entirely lacking.

ABSTRACTS *

(*From Recent Articles of Interest to the Iron and Steel Metallurgist*)

The Classification, Properties and Utilization of Special Ternary Steels. L. Guillet. Paper before the Société des Ingénieurs Civils de France, June 17, 1904. — The author defines at first what he understands by a ternary steel: an alloy of iron, carbon and of a third body, metal or metalloid. He briefly recalls what he has already said on the subject of nickel, manganese, chrome and tungsten steels.

He then studies the influence of molybdenum, which plays exactly the same rôle as tungsten, with the exception that four times less molybdenum than tungsten is required to produce the same effect. The diagram of molybdenum steels is besides quite as simple as that of tungsten steels.

Cobalt, in spite of its close relationship to nickel, brings about, at least as far as 30 per cent, no modification in the structure and properties of ferro-carbon alloys.

Silicium, on the contrary, precipitates carbon to the state of graphite as soon as there is five per cent of it contained in the steel; it forms up to 15 per cent a solid solution with iron; we must add, however, that in certain steels containing from seven to ten per cent of silicium, one can remove very small quantities of the combination Fe_2Si. Beyond 15 per cent, the composition known as FeSi appears.

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* Note. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

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Titanium and tin do not give the same results as silicium; in the steels which have been studied and which contained up to ten per cent of tin or titanium, all the carbon is in the state of carburet of iron, whilst titanium is always in solution, the tin forms a combination which appears clearly under the microscope, but which has not yet been resolved into its parts.

Mr. Guillet studies in detail the constitution, properties and possible influences of aluminium and vanadium steels.

Vanadium steels have been very carefully studied, in cases in which the amount of vanadium varied from 0.2 to 10 per cent.

In the steels containing 0.200 per cent of carbon, as long as the vanadium does not exceed one per cent, only pearlite is found; beyond that white specks appear, the size and number of which increase according as the vanadium increases; at three per cent there is no longer any pearlite. The special element is in a carburetted substance. Vanadium begins by saturating the iron, then influencing the carbon. In steels containing 0.800 per cent of carbon, white specks appear after 0.7 per cent; but it is only at seven per cent of vanadium that all the carbon is in the state of carbide.

In concluding, Mr. Guillet shows that ternary steels are divided into the following five classes:

(1) Pearlite (all elements give pearlite steel, when their percentage is not very high); (2) Martensite (nickel steel, manganese and chrome); (3) Nickel or manganese steels; (4) Chrome, tungsten, molybdenum and vanadium steels; (5) Silicium steels.

Pearlite nickel steels have a brilliant future before them; tin steels on the contrary are very fragile. Silicium steels and chrome and vanadium steels containing carburet have no application.

Mr. Guillet concludes in showing how this study, which has allowed him to trace diagrams of extreme simplicity, simplifies a question which appeared so complex. "Engineering Press Monthly Index Review," July, 1904. **No. 229.**

Molybdenum Steels. Léon Guillet. "Revue de Métallurgie," July, 1904. 6,000 w., illustrated. — Two series of alloys have been prepared, the first containing about 0.2 per

cent, and the second 0.8 per cent carbon with molybdenum varying from nothing up to 15 per cent. With the first series after ten per cent molybdenum is exceeded the alloys will not forge, a similar point being reached in the second series at a content of five per cent. The micrography of these steels may be summarized as follows: First series. Steels containing from 0.45 per cent to 1.0 per cent molybdenum present pearlite in a more divided condition than is usual with ordinary carbon steels. At two per cent molybdenum a change of structure is noted, and pearlite whilst present is exceedingly fine. At five per cent pearlite is absent, and the structure is characterized by a special constituent formed of long and fine filaments. Second series. The pearlite of the second series is extremely divided, and at 1.2 per cent molybdenum isolated white grains of the special constituent appear which increase with corresponding increments of molybdenum. At ten per cent molybdenum a eutectic formed by the special constituent and iron appears. The work indicates the special constituent to be a carbide, but its composition has not yet been determined. The micrography of molybdenum steels gives similar results to those of tungsten, but it may be noted that the structural transformations are obtained with a quarter the amount of molybdenum. In other words, molybdenum is four times as active as tungsten. The mechanical properties of the alloys tested are summarized in the table below. These results permit of the steels being divided into two classes according to their structure; thus Class I, steels of a pearlitic structure, and Class II, steels containing the special constituent (carbide). The pearlitic steels give high elastic limits and breaking loads with good reductions of area and normal elongations. They also offer a good resistance to shock, but are comparatively hard. Steels of the second class, are fragile, of a remarkable hardness, the latter property rendering them suitable for tool steels. In fine, the influence of molybdenum may be stated as similar to that of tungsten, one part of the former giving a similar result to four parts of the latter.

Series I

Carbon	Molyb-denum	Max. Stress	Elastic Limit	Elongation Per Cent	Reduction of Area Per Cent	Frémont Test Kilogram-meters	Hardness Brinell
0.188	0.450	48.9	37.6	18.5	69.3	24	131
0.158	1.005	64.0	39.5	17.0	66.5	27	118
0.138	2.290	82.8	67.7	7.5	12.1	15	212
0.289	4.500	130.6	103.2	6.0	7.5	3	387

Series II

Carbon	Molyb-denum	Max. Stress	Elastic Limit	Elongation Per Cent	Reduction of Area	Frémont Test Kilogram-meters	Hardness Brinell
0.735	0.504	115.2	82.8	7.0	7.5	1	286
0.811	1.210	120.5	78.3	6.5	5.6	1	293
0.814	1.980	143.1	101.7	4.0	5.2	2	332

"The Engineering Review," September, 1904. **No. 230. H.**

Titaniferous Iron Ores. Nelson P. Hulst. "The Iron Trade Review," September 1, 1904. 5,000 w. — Extract from a paper read before the Lake Superior Mining Institute, August 17, 1904. **No. 231. A.**

The Ontario Iron Ranges. A. B. Willmott. "The Iron Trade Review," September 8, 1904. 1,800 w. — A paper read before the Canadian Mining Institute. **No. 232. A.**

Iron Ore Mining in Scandinavia. W. F. Wilkinson. "The Iron Age," September 1, 1904. 4,000 w. — Abstract of a paper read before the Institution of Mining and Metallurgy, London, England, June 16, 1904. **No. 233. B.**

Modern Blast-Furnace Construction. From the Drawing office point of view. I. G. Bayley. "The Iron Age," September 29. 5,000 w. — A detailed description of a method for preparing as quickly as possible a complete set of drawings necessary for the erection of a modern blast-furnace plant. **No. 234. B.**

Direct Casting from the Blast-Furnace. "The Engineering Review," September, 1904. 1,200 w., illustrated. — This article describes the manufacture of castings direct from the blast-furnaces as conducted at the works of Thomas Butlin Co., Ltd., of Wellingborough, England. **No. 235. B.**

The Mesta 40-Inch Slabbing Mill. "The Iron Age," September 29, 1904. 1,500 w., illustrated. — A description of a new 40-inch slabbing mill recently installed at the National Tube Company's plant, McKeesport, Pa. **No 236. B.**

The Manufacture of Steel Castings. W. A. Herron. "The Iron Trade Review," September 29, 1904. 3,000 w. — Includes an outline of the crucible, Bessemer and open-hearth processes, methods of molding, inspection, etc. **No. 237. A.**

The Introduction of High-Speed Steel Into a Factory. A. D. Wilt, Jr. "The Engineering Magazine," September, 1904. 4,000 w. — A consideration of the management problems connected with the introduction and use of high-speed steel. **No. 238. B.**

The Schneider Works in France, With Details of the Plants at Creusot and Havre. E. Guarini. "The Iron Trade Review," September 1, 1904. 4,000 w., illustrated. — An illustrated description of these famous French steel works. **No. 239. A.**

The Micro-Structure of Brass. Arthur H. Coats. "Technics," September, 1904. 1,000 w., 9 photo-micrographs. — The author discusses the effect of annealing upon the structure of brass containing 70 per cent of copper and 30 per cent of zinc. **No. 240. C.**

Notes on the Metallography of Steel. Bradley Stoughton. A paper presented to the International Congress, St. Louis, Missouri, October 3 to 8, 1904. 45,000 w., illustrated. — This paper consists of an exhaustive and authoritative exposition of the development and present state of the metallography of steel. **No. 241.**

"The Foundry." The October (1904) issue of "The Foundry" contains the following articles of interest:

"Use of Manganese in the Cupola or the Ladle." N. W. Shed.

"Cupola Fan Practice." W. H. Carrier. A paper read at the A. F. A. Convention, Indianapolis, June, 1904. (See abstract No. 190, *The Iron and Steel Magazine* for August, 1904.)

"Fan Blowers for Cupola Work." G. W. Sangster. A paper read at the A. F. A. Convention, Indianapolis, June, 1904.

"Cupola Practice." Harry Willis. A description of cupola practice in one of the best foundries in New Zealand.

"Molding Machine Practice." F. W. Hall. **No. 242. A.**

EDITORIAL COMMENT

Maunsel White

Maunsel White was born in Madison Parish, Louisiana, March 15, 1856. After spending his early life on a sugar plantation he went to Georgetown College, D. C., but soon determined to take up engineering work, and to that effect entered the railroad shop at Weatherly, Pa. In 1875 he was admitted to the Stevens Institute of Technology of Hoboken, N. J., graduating from that school in 1879. In December of the same year Mr. White entered the employ of the Bethlehem Iron Co. (now the Bethlehem Steel Co.) at South Bethlehem, Pa., and has ever since been connected with these works. The Bethlehem Iron Co. was then one of the leading producers of Bessemer steel which under the management of John Fritz had acquired a reputation for superior excellence. Mr. Fritz was desirous of still further improving the quality of this metal, and experiments were undertaken with that end in view. This necessitated the introduction of new and more extensive tests, which were entrusted to Mr. White, who also took charge of the chemical laboratory in which all the materials were analyzed and the charges made up accordingly. This brought about greater uniformity of working and product which in turn made possible the production of higher carbon with greater regularity. Higher carbon rails were made to meet the constantly inceasing wheel loads and the general excellence of the steel led to its introduction for various other uses, and early in the '80's Bessemer steel was made ranging from 0.08 to 1.10 per cent carbon. This product supplanted in many cases the far-famed steel of Sweden and the best open-hearth steels of Europe. The U. S. Government depended almost solely upon this source of supply for the steel for the army rifle barrel, as it proved in open competition superior to any other steel, either crucible or open hearth. During this period Mr. White had charge of all the special steels made, and great credit is due to him for his being able to produce a steel which was then preferred to any other make.

After the abandonment, at South Bethlehem, of the Bessemer process, Mr. White devoted much time to the study of nickel steel and of its development as well as to the production of special crucible steel alloys. In conjunction with Mr. T. W. Taylor he developed a treatment for special self-hardening steels, which was patented in 1901 and which it can be truly said has revolutionized the machining of steel. We do not hesitate to express it as our opinion that the Taylor-White process constitutes the most important advance made in the metallurgy of steel since the invention of the Bessemer process and the successful production of steel in a reverberatory furnace. The inventors are entitled to the gratitude and admiration not only of metallurgists and steel workers, but of the whole engineering profession — nay, of the world.

The following short sketch of the development of the Taylor-White process, in Mr. White's own words, will be found of interest:

"It was decided to adopt one brand of self-hardening steel for use in our shop and to this end samples were obtained of the various brands on the market and a thorough test made of each.

"The best treatment was investigated and this consisted in heating the tool after forging to successive ascending heats and in making a test of the cutting properties after each heating. It was found that the tools showed deterioration after passing the heats usually used, some failing after 1,550° F., others after 1,650° F., according to composition. Going still higher in heat it was found that a recovery began in some at 1,725° F., in others not till 1,850° was reached and then improvement increased very rapidly up to the point at which fusion just began at the thinner edges of the tool. It was further found that chromium was essential for this improvement. Steels without this element showed no advantages from the high heat. Mushet was one of this type. With 0.5 per cent chromium there was some improvement which increased rapidly up to three and then more slowly up to six and seven per cent. Beyond this point the steel is too difficult to forge. After the high heat it was found that the tool made further improvement by running in the lathe and grinding several times. This we found was due to the heating in cutting and for this was substituted a second heating at a low heat which was carefully determined by exhaustive experiments to obtain maxi-

mum results. With this double heating, tools were produced which would start off at maximum speed and it was found that large batches could be treated and extremely uniform results obtained, something that had never before been possible.

"Some idea of the thoroughness of these tests may be obtained from the fact that nearly 200 tons of steel was cut up into turnings and that the investigation required a period of two years and the services of seven or eight trained experts.

"A 40-foot lathe was shown at the Paris exhibition cutting soft steel at a speed of 150 feet per minute with a three-sixteenths-inch depth of cut and one-sixteenth feed, the turnings coming off with their edges red hot. It was regarded as a most phenomenal performance and attracted wide attention from the engineering world.

"The process has led to the redesigning of many machine tools and has changed completely many methods of manufacture. In several shops where the process is intelligently used the output has been trebled with an insignificant increase of cost for increased driving power."

Messrs. White and Taylor were each awarded a gold medal at the Paris exhibition and received also the Elliot Cresson medal of the Franklin Institute.

IRON AND STEEL METALLURGICAL NOTES

Prices of Iron and Steel to Foreign Buyers.—With regard to the prices at which our iron and steel products have been sold abroad it can be said with entire frankness that, while there have been some sales made at lower prices than have been charged to domestic consumers, the large majority of the sales have been made at the same prices as have been obtained at home or at even higher prices. When lower prices have been charged the inducement to do this has been to dispose of a surplus, as during the years of depression following the panic of 1893 or during the reactionary year 1900, or to secure entrance into a desirable foreign market, or to retain a foothold in a foreign market that has already yielded profitable returns. These reasons for the occasional cutting of prices require no defense. They are akin to the reasons which daily govern sales of manufactured and all other products in domestic markets.

Even in years of prosperity it sometimes happens that a rolling mill or steel works, when running to its full capacity, produces a surplus of its products beyond the immediate wants of its customers or of the general market. If this surplus can be sold abroad, even at prices below current quotations, it is better to do this than to reduce production by stopping the rolling mill or steel works for a few days or even for one day. The men would not only lose their wages during the stoppage but the manufacturers would lose in many ways. As one incident of the stoppage the home consumers of their products could not be supplied so cheaply as when the plants are running full. A moment's reflection will convince any candid man that the manufacturing establishment that is not kept constantly employed, whether it produces iron and steel, or cotton goods, or woolen goods, or pottery, or glassware, or any other articles, cannot be operated so economically for its owners or so beneficially for its customers as the establishment that is kept running six days in the week and every week in the year.

Other countries recognize the economic necessity of keeping manufacturing establishments fully employed. A despatch from Berlin, dated February 13, 1904, says: "Public Works Minister Budde, before the budget committee of the Prussian Diet to-day, defended the practice of the steel rail syndicate in selling cheaper abroad than at home. He said that the practice was in the interest of the employés, as it gave them steadier employment and prevented shut-downs. The giving of steadier work also was in the interest of the manufacturers, since it diminished the cost of production." Mr. Chamberlain's Tariff Commission has just assigned short time at English iron and steel works as a leading factor in increasing the cost of making iron and steel at these works. The London "Statist" for July 23 says: "In the opinion of the firms that have replied to the inquiries, and the witnesses who have come before the Commission, short time is of infinitely greater importance in increasing the cost of production than all the other general causes mentioned."

It should also be remembered that our tariff legislation for at least a generation has encouraged our manufacturers to seek foreign markets by remitting nearly all of the duties levied on imported raw materials when these raw materials enter into the manufacture of exported finished products. Under the operation of this drawback system our iron and steel manufacturers have been able to manufacture their products intended for foreign markets at a much lower cost than they could supply similar products to home consumers. Iron ore, spiegeleisen, and ferro-manganese, for instance, enter into the composition of steel rails and when imported are dutiable, but 99 per cent of the duty paid on any of these products is remitted when they are used in the manufacture of rails for export. The London "Engineering" for January 17, 1902, says of this drawback system: "A certain amount of trade is brought into the country that would otherwise be missed and no one loses anything." It might have added that the raw materials we import and subsequently export in finished forms furnish employment to American workingmen.

Finally it may be said that nearly all the money that is paid by foreigners for American steel rails or for other steel products of American manufacture, no matter at what prices

they may be sold, and irrespective of the sources of supply of raw materials, is paid to American labor that is engaged in their manufacture, and that fully the half of this money finds its way into the pockets of American farmers. Both the workingman and the farmer should be thankful that our protective tariff policy has enabled our manufacturers to sell a part of their products in foreign markets, even if they sometimes sell at a loss. "The Bulletin of the American Iron and Steel Association," October 10, 1904.

Standard Specifications for Testing Materials. — The first step towards the adoption of international standard specifications is the use of standard test pieces, in order that the results may be comparable. The tension test pieces proposed by the Engineering Standard Committee of England will no doubt come into general use, as they seem to be a practical solution of this troublesome problem. It is to be hoped that a series of tests will be made here on universal plates, shapes and eye-bar flats, using test pieces of 1½ inches, 2 inches and 2½ inches in width for different thicknesses of material, in order to bring out the effect of varying widths on the percentage of elongation, when tests are made under the conditions in use in this country. One set of tests should be made with the slowest pulling speed in use, and another with the fastest speed of the testing machines in ordinary practice. This no doubt would repeat to a certain extent, the recent tests made by Professor Unwin, but it would give some very valuable information. It might show that it would be desirable to embody in the specifications a clause to regulate the pulling speed, in order to keep all the conditions under which tests are made a little more uniform than they are at this time.

The next step, of course, is to decide on the best form of test piece for the thick eye-bar flats, say 1¾ inches and over in thickness, in order that results may be nearer those of the full size tension tests of the finished eye-bars. Other things being equal, the larger the test piece the more reliable the results; but if square test pieces equal to the thickness of bar are used, the ordinary testing machines are not large enough to pull them. The thin slice cut from the bar with the width equal to the thickness of the bar does not give satisfactory results, but

it is often used. Recourse is had to the round test piece for these heavy bars, and the results of these tests are not all that could be desired. This heavy material gives more trouble than any other, and it seems as though this would be a good time to take up and thoroughly investigate the forms of test pieces best suited to give the most reliable results. In England, of course, they were not bothered with this, as they do not use upset eye-bars, while in this country it is a matter of vital importance, as the size of eye-bars increases every year.

Standard test pieces for bending have been considered by some of the committee at work on specifications, and they have generally decided on the following: "Full sized material for eye-bars and other material one inch thick and over, tested as rolled, shall bend cold 180° around a pin the diameter of which is equal to twice the thickness of the bar without fracture on outside of bend." This bending test is considered by many engineers to be a much better check on brittle steel than the ordinary tension tests.

In all the present specifications allowances are made in the percentage of elongation and the requirements in the bending tests for the heavy material. They are not as severe as for steel of medium thickness, and it is an open question if engineers have not gone too far in these allowances, in other words, if much better heavy material cannot be rolled than that supplied in ordinary every-day practice under the present specifications. This applies to rails as well as to any other heavy rolled material, and it opens up one of the most important questions to both the engineer and the manufacturer. It is a matter that depends largely on the amount of work in rolling put on the steel at a low heat, and the low finishing temperature in rolling. If this could be done without any additional cost, it would be a very simple matter to settle; but as it involves cutting down the daily tonnage with a corresponding increase of cost, the question comes up as to who is to pay for this. Some specifications are in use that cover this important matter of finishing temperature directly, and others cover it by increasing the requirements of the physical tests, which in turn require a much lower finishing temperature. As the importance of this becomes more generally understood these tests will come into more general use, which will result

in better steel for the consumer at perhaps a slight increase in cost. "The Railroad Gazette," September 9, 1904.

A Process of Hardening Iron and Steel. — According to the "Mechanical Engineer" the Feuerfeste Industrie Gesellschaft of Düsseldorf has introduced a patented process of hardening iron and soft steel. The carbon requisite for the tempering is obtained by means of carbides and certain fluxes. For instance, a mixture of silicium carbide (SiC) and sodium sulphate ($Na_2\ SO_4$) is applied to cold iron or steel and then heated to redness with it, or the red hot metal is covered with the mixture. The reaction is so rapid that even thin objects can be hardened on one side. Within a short time a plate two mm. or three mm. thick becomes hard enough on one side to resist the best tempered steel tool, while the other remains wholly soft. Interesting experiments were made with armor-plates. A plate of ordinary Martin steel (70 kilos strength) was smeared six mm. thick with the mixture, then a second plate was placed upon the latter, and the "sandwich" maintained at red heat for a couple of hours, after which it was cooled in oil. At a distance of 20 meters the hardened sides of these plates received a dozen bullets from a German rifle, model '98, without showing signs of a rip. A five mm. plate of common Siemens-Martin steel, treated in the same way, was tested at a range of 100 meters. The impression of the bullet was very faint, nor could any cracks be detected. "The Iron Trade Review," September 29, 1904.

The March of Open-Hearth Steel. — Despite the fact that Bessemer steel production in 1903 fell 6.1 per cent below that in 1902, the record of open-hearth steel production, as presented elsewhere in this issue, shows an increase of 2.6 per cent, and this also notwithstanding the handicap of a slight decrease in acid open-hearth production. Basic open-hearth steel manufacture is really more separate from the acid open-hearth industry than it is from the Bessemer steel industry, so far as concerns the uses to which the product is put, while it is almost equally separated from either as regards the character of its raw materials. Before the basic industry assumed important proportions, however, the acid process had shown a rapid increase.

The remarkable growth of the open-hearth steel industry as a whole can be strikingly shown by noting the short periods which have been required for the production to double. This is brought out in the following table, which, starting with the production in 1903, presents successive bisections and then selects the year most nearly conforming to the bisected tonnage, the period between such years being noted:

Open-Hearth Steel Ingots and Castings, Gross Tons

1903 production and bisections	Closely conforming years with production		Interval in years
5,837,789	5,837,789	1903	
			4
2,918,894	2,947,316	1899	
			2
1,459,447	1,608,671	1897	
			4
729,723	737,890	1893	
			4
364,861	374,543	1889	
			3
182,430	218,973	1886	
			6
91,215	100,851	1880	
			1
45,607	50,259	1879	
			2
22,803	22,349	1877	
			2
11,401	8,080	1875	
			1
5,700	6,250	1874	
			2
2,850	2,679	1872	
			2
1,425	1,339	1870	
			1
712	893	1869	

It happens that in selecting the nearest year it has been necessary, since 1879, to take a year in which the production exceeded the bisection. The comparison has been followed back to the earliest times, when the production according to present standards appears insignificant, merely as some re-

joinder to the oft repeated pronunciamento that we cannot expect nearly the same relative expansion in the future that we have had in the past. As a matter of fact we can have no argument at all that we have stopped growing, until we do stop. The table, then, shows that from the time the production ran into six figures the average interval for doubling the production has been 3.4 years, while prior to that time 2.125 years were required. The difference is certainly not very great. Furthermore, we quadrupled in eight years from 1889 to 1897, and quadrupled again in only six years, from 1897 to 1903. It is true that 1896 fell only a little more short of quadrupling 1889 than 1897 had to spare, but on the other hand 1902 came almost as near the mark as 1903, so that we could say that, substantially, we quadrupled in seven years from 1889 to 1896, and quadrupled again in six years, from 1896 to 1902.

Basic open-hearth steel production alone more than doubled from 1897 to 1900, while the production of even 1902 was more than a quadruple of 1897 — only five years. Bessemer steel production has had a vastly slower growth. It quadrupled in five years from 1872 to 1877, then in nine years from 1877 to 1886, while the last quadrupling required 16 years. "The Iron Trade Review," September 29, 1904.

The Microscope in the Study of Steel. — In a discussion on a paper, "Variations in Structures and Tests of Steel," before the West of Scotland Iron and Steel Institute, some mention was made of the limitations of microscopic analysis. W. Cuthill remarked that the micrograph tells nothing of the composition of steel, whether high or low in impurities, but this we learn from the chemist. It tells as little of the mechanical properties of steel, whether high or low in strength and ductility, but the testing machine provides the information. It has, therefore, a distinct province of its own, and that is to reveal the work and heat treatment steel has undergone, which neither the chemist nor testing machine can indicate with any reliability. In this respect it should very usefully fill a gap in the investigation of many puzzling and difficult problems in the behavior of finished steel. For instance, has it been burned, or has it been finished in the rolling at too high a temperature? A. Campion said he thought that in some cases it was possible

to gain an idea as to the amount of certain impurities which were present by microscopic analysis; for instance, steel containing much arsenic or phosphorus. Steel containing a high percentage of manganese also showed a structure quite distinct from that of steel containing a small amount of manganese. Regarding the possibility of distinguishing between steel which had been overheated, and that which had been burnt, he thought a steel that had actually been burnt was one of the easiest things to detect under the microscope. F. W. Harbord wrote that microscopic analysis, like many other things, has suffered from the somewhat extravagant claims made by some of its early exponents, and the authors of the paper had done a very useful piece of work in defining the limitations of microscopic analysis, by showing that although the details of the structure may vary in various parts of a bar, the general structure remains the same. Provided that the heat treatment has been the same, the educated eye has no difficulty in discriminating between the general as distinct from the detail structure, and although the size of the grain may vary from the outside to the center, or other parts of a large bar, the micro-constituents are clearly defined. In certain cases of marked segregation, when the metal is high in sulphur or manganese, the former may be clearly seen as buff colored round or elongated spots, the latter by the alteration in the structure of the material. The real value, however, of microscopic work is that we are able to determine the marked influence of heat treatment, and although similar steels heated or cooled under identical conditions will often vary considerably in their detailed structure, the general type of structure of annealed or rapidly cooled, or quenched steels is so characteristic that it can be at once identified by the practiced observer. He was glad to see that the importance of using the microscope as an adjunct to other methods of testing, and not as an independent method of investigation, had been emphasized by the authors, as it could not be too strongly insisted upon, that it does not replace, but only supplements other methods of examination. "The Iron Trade Review."

The Strength of Steel at High Temperatures. — Professor C. Bach has presented in the "Zeitschrift des Vereines Deut-

scher Ingenieure" the results of an elaborate series of tests of the strength of steel at high temperatures. Bars from three different works were tested, these being distinguished by the letters O, K and M. Of the bars O, four were subjected to tensile tests at ordinary temperatures, and successive lots of four to tests at the temperatures, 200°, 300°, 400°, 500° and 550° C. At ordinary temperatures the strength of the steel was, for bar No. 2, for example, 27 tons per square inch, the ultimate extension on a gauge length of eight inches 26.3 per cent and contraction of area 46.9 per cent. The results of the tests showed that the strength increased up to 300° C. by about 3.17 tons per square inch, and from this temperature onward the strength fell, roughly in proportion to the temperature, to 13.1 tons per square inch at 550° C. The ultimate extension decreased from 25.5 per cent at ordinary temperatures to 7.7 per cent at 200° C., from which again it rose to 39.5 per cent at 550° C. The contraction of area also fell at 200° C., but did not commence to rise until the temperature was above 300° C. In the case of the bars from the works distinguished by the letters K and M, tests were made by keeping the loads on for a considerable time. This prolonging of the action of the load had no effect until the temperature reached 300° C., at which point it caused a slight decrease of strength, and at 400° and 500° a greater decrease. As regards the effect of prolonged loading on the extension and contraction between the temperatures of 300° and 400° C. it caused an increase in both, but from 400° C. the extension and contraction under prolonged loading decreased until at 500° C. they were lower by from 20 to 25 per cent than with ordinary duration of test.

Professor Bach draws the conclusion from his investigations that for steam boilers, piping, etc., the strength of steel should be tested at the higher temperatures; and he is of opinion that this conclusion is justified not only by his experiments, but from the well-known fact of the brittleness of steel when worked at a blue heat. "The Iron Age," September 8, 1904.

Brazing Cast Iron. — Cast iron has always been a difficult material to solder or braze and early attempts invariably re-

sulted in failure. There are many instances, notably broken gear teeth or similar materials, upon which the brazing process can be quite advantageously employed, and we are pleased to say that the problem of brazing cast iron has finally been solved. We have recently seen many examples of brazed cast iron and had the pleasure of personally testing them. The results were very gratifying, so much so that we are free to confess that cast iron brazed after the proper method is a reliable article. In every instance in which the cast iron was brazed blows from a hammer failed to break the casting in the brazed joint, but the fracture occurred outside of it. The quality of the cast iron does not seem to affect the brazing process, but all kinds braze equally as well.

The principle of this modern brazing process consists in the principle of burning out the carbon and silicon on the surface. These elements are always present in cast iron, otherwise it would not be cast iron, and prevent the union of the brazing solder with the metal. By the application of a mixture of oxide of copper and borax as a flux in the brazing, the carbon and silicon are burned away with the reduction of the oxide of copper to metallic copper which immediately unites with the metal. Of course, the usual brazing solder is employed, but it is to the burning away of the carbon and silicon that the success of the process is due. We believe that there is much in store for this process, as there are many cast iron parts of machines or appliances which may be readily brazed together when broken, and not only the expense of a new casting saved, but, what is usually far more necessary, the great saving in time. "The Metal Industry," September, 1904.

Canadian Duty on Rails in Force. — A proclamation was issued on August 27 by the Canadian Government to bring into force the act of 1903 imposing a duty of $7 a ton on steel rails. This duty was to take effect when sufficient evidence was furnished to the Government that rails of the best quality were being made in Canada in sufficient quantity to supply the ordinary demand. As a rail mill at Sault Ste. Marie is now in operation, the act becomes effective. The duty will not apply to any rails actually contracted for abroad prior to August 27, but such rails must be imported into Canada not

later than November 30, 1904, and must be laid on the track not later than February 28, 1905. The plant at the Soo resumed August 23. It was not expected that rails would be rolled before September 1, but Superintendent Lewis pleasantly surprised the Canadian and American cities at the Soo by starting a week earlier. The blast-furnaces will soon be blown in. "The Iron Trade Review," September 1, 1904.

Sale of the Bethlehem Steel Company Plant. — Three hundred thousand shares of stock of the Bethlehem Steel Company, the entire capital stock of the company, was sold for $7,500,000 September 2 by former United States Senator James Smith, Jr., receiver for the United States Shipbuilding Co., acting as special master under direction of John William N. Lanning of the United States district court. The par value of the stock is $15,000,000. The stock was bought in by William C. Lee, the only bidder, president of the Standard Trust Co., of New York, which held the stock as trustee, and the shares become subject to an agreement between Charles M. Schwab and the reorganization committee for the United States Shipbuilding Co. Mr. Lee, as soon as the stock was knocked down to him, handed Receiver Smith a check for $100,000, as required by the order of the court directing the sale of the stock under the decision in the joint foreclosure suit brought by the New York Security & Trust Co. and the Mercantile Trust Co., of New York, against the United States Shipbuilding Co. and others. Mr. Lee bought in the stock for the reorganization committee of the United States Shipbuilding Co. for the benefit of the bondholders. The $7,500,000, if paid in cash, will be used to take up bonds of the United States Shipbuilding Co. or that total may be paid in the bonds of the company. The sale means that Schwab is now in control of Bethlehem Steel. "The Iron Trade Review," September 8, 1904.

The New England Foundrymen. — The September meeting of the New England Foundrymen's Association was held at the Exchange Club, Boston, Wednesday evening, September 14. President B. M. Shaw was in the chair. Before dinner F. R. Fletcher of the Library Bureau read a paper, entitled "Foundry and Factory System," in which he described meth-

ods applicable to the foundry and pattern shop. W. B. Snow of the B. F. Sturtevant Company, in answer to questions, told something of the workings of the system in use by his company, especially as it fixed responsibility where it belonged, and did away with the bickerings between departments as to where blame for poor work should rest. After dinner Kenneth Falconer of Montreal read a paper covering the general subject of foundry systems, handling the question from the standpoint of the accountant. Resolutions were adopted on the death of Alfred J. Miller of Whitehead Bros., Providence, R. I.

The Foundrymen's Association has prepared an attractive programme of the season's meetings, as follows: October 12, C. H. Thomas, Newark, N. J., president of the Foundry Foremen's Association, and Thomas D. West, Sharpsville, Pa., subject, "The Casting of Iron"; November 9, H. E. Field, Pittsburg, Pa., and Dr. Richard Moldenke, Watchung, N. J., subject, "The Chemistry of Iron"; December 14, George H. Hull, president of the American Pig Iron Storage Warrant Company, and Archer Brown of Rogers, Brown & Co., subject, "The Finance of Iron"; January 11, annual meeting; February 8, Albert Sauveur, Boston, and Henry Souther, Hartford, Conn., subject, "Physics of Iron"; March 8, O. P. Briggs of the Committee of the National Founders' Association, and another gentleman, to be announced later, subject, "How to Obtain Skilled Labor"; April 12, a representative of the American Mutual Liability Insurance Company, and James Gould of Jesse Gould & Son, Boston, subject, "Insurance"; May 10, speakers to be announced, subject, "Foundry Supplies and Equipment"; June 14, E. H. Mumford, Tabor Mfg. Company, Philadelphia, and another speaker, subject, "Molding Machines." "The Iron Age," September 22, 1904.

REVIEW OF THE IRON AND STEEL MARKET

There has been a noteworthy improvement in the iron and steel trade during October. Demand has increased materially, and to the extent of influencing prices in the case of pig iron. In all branches of the trade there is a firmer and more hopeful feeling and confidence is entertained that the improvement, while there may be a lull in December, will be continued next year.

In finished products, the chief increase in demand has been through the liberal buying of steel cars by the railroads, while repairs to old cars and buying of wooden cars have been contributing factors. At the present time the steel car builders have orders for between 20,000 and 25,000 all-steel cars on their books, which will keep them busy until February, while there are also large orders for steel underframed cars. This has made excellent business for the plate mills, and most of the regular plate mills are now comfortably booked with business to the end of the year.

The continuance into October of the moderately heavy buying of pig iron noted in our report of a month ago tended of itself to advance prices, and two important influences accentuated this tendency. The first which became apparent was the rather meager supply of ore on the part of some merchant blast-furnaces, which did not make contracts at the beginning of the ore season on the basis of full operation through the winter. The season is now nearly over, and while the total movement of ore will be good, compared with pig iron production of the year, the distribution is not so good, as the leading steel interests have brought down somewhat more than their share. The result is that if there were orders for pig iron sufficient to keep all merchant furnaces in operation to the opening of navigation next year, sufficient ore would not be available, and the competitive field is thus restricted. About the middle of October the long continued dry weather in the Connellsville coke region made itself felt, many independent coke operators being compelled to decrease production of coke just at the time when demand was increasing. The lead-

ing steel interest, with some other interests, began buying coke liberally and some sellers at once withdrew entirely from the market, while all others sharply advanced their prices.

The net result of all these influences has been to advance pig iron prices sharply, and by fully a dollar a ton during October. After the advance was well under way there was quite a decrease in actual transactions, although inquiry continued good, and the market is, in a sense, resting on the advance and awaiting results. There have been reports that the leading interest would buy a large block of pig iron, and this may also have had something to do with the result.

Effective October 19 discounts on merchant pipe were reduced one point, under the lead of the principal interest, effecting an advance of approximately $2.00 per net ton on iron and steel pipe, both black and galvanized. If anything, the advance seems to have stimulated demand, which had been far from excessive, and a further advance is considered not altogether improbable. In sheets the market is not quotably higher, but the regular prices are now very strictly observed, with inquiry excellent. Tin plates have also been looking up. In wire the turnover has remained fairly good, and there is a possibility of an advance. In other finished steel lines prices are unchanged, and changes are not very probable. In common iron bars the market has continued to stiffen, and 1.30 cents, f.o.b. Youngstown, is now the recognized market, making an advance of say $1.00 a ton during the month.

Pig Iron. — During the first half of October current sales of foundry and forge iron were excellent, first at our prices of a month ago, and later at advances of 25 to 50 cents a ton. Towards the close of the month sales have been lighter, as quoted prices represent an advance of about a dollar a ton; we note, however, one sale of 4,000 tons of forge at $12.80, Pittsburg, or substantially the advanced figure. There has been good demand for basic pig throughout the month, but as with foundry most of the buying has been done at the lower figures. In Bessemer one outside steel interest is reported to have bought upwards of 30,000 tons, at from $13.35 to $13.60, delivered Pittsburg, while other interests have bought smaller quantities. The month closes with the market in a decidedly nervous condition, and prices difficult to quote. We name approximate asking prices as follows: F.o.b. Mahoning or Shenango valley furnace, forge, $12.00; No.

2 foundry, \$13.00 to \$13.50; Bessemer, \$12.75 for remainder of this year and \$13.00 for next year; basic, \$12.50 to \$12.75. Delivered Pittsburg: Forge, \$12.80 to \$12.85; No. 2 foundry, \$13.75 to \$14.35; Bessemer, \$13.60 to \$13.85; basic, \$13.35 to \$13.60. At Philadelphia: No. 2 X foundry, \$14.50 to \$14.75; basic, \$13.50 to \$13.75; standard gray forge, \$13.50 to \$13.75. At Chicago: Northern foundry No. 2, \$13.50 to \$14.00. Alabama prices cannot be quoted; the furnacemen generally have withdrawn from the market, as they are quite well sold up to the end of the year with the decreased production due to the coal miners' strike.

Steel. — The official prices are quite rigidly maintained, at \$19.50 for 4 × 4 and larger billets, and \$21.50 for small billets and sheet bars, long lengths, f.o.b. Pittsburg, plus freight to destination. The steel interests have been considering the question of advancing prices, but nothing is likely to be done for a few weeks.

Plates. — As noted, the plate mills generally are well filled with business. Official prices remain as last quoted, and are being rigidly maintained, based on 1.40 cents for tank quality, quarter inch and heavier, over 24 inches wide and not over 100 inches wide.

Shapes. — The mills are doing a fair amount of business, at prices last quoted.

Bars. — Tonnage in both iron and steel bars is fairly satisfactory. Steel bars are unchanged in price, while common iron bars are quite firm at 1.30 cents, Youngstown, or 1.35 cents, Pittsburg.

Sheets. — Demand for sheets has been very good, and most producers are well provided with orders. We quote No. 28 gauge black sheets at 2.10 cents, f.o.b. Pittsburg, in carload or larger lots, and galvanized at 80 and 7½ per cent off list.

Coke. — There is a great deal of inquiry for coke for next year, but transactions are not in accord, as many producers refuse to quote at this time, and others name prices which surprise buyers. Strictly Connellsville coke is held at \$1.65 to \$1.75 for furnace and \$2.10 to \$2.25 for 72-hour foundry.

Ore Rates. — Lake rates on ore have been advanced five cents, the rate from the head of the lakes being now 70 cents.

Republic Iron and Steel Company. — The annual report of this company for the year ending June 30, 1904, reflects the un-

satisfactory condition of the trade during the fiscal year. The company consolidated, in 1899, a large number of iron mills, together with some blast-furnaces. It has since gradually built up a standard Bessemer steel plant at Youngstown, with two ten-ton converters, and has rebuilt its Pioneer blast-furnaces in Alabama so that they now constitute one of the finest blast-furnace plants in the south. The rolling mills have also been improved somewhat. The profits for the year, after deducting all expenses excepting improvements, renewals and repairs, are reported at $1,306,068.05, leaving, after deducting $890,640.07 for reconstruction, renewals and repairs and $669,616.41 for depreciation of inventory, a net loss of $254,188.43. A preferred dividend of 1¾ per cent on the preferred stock, or $357,295.75, was paid October 1, 1903, and this, with the net loss, reduces the surplus to $2,636,722.10. A condensed statement of the company's operations for its entire life, May 1, 1899, to June 30, 1904, shows aggregate gross profits of $15,407,993.88, from which was charged off $8,688,370.85 for depreciation, while dividends of $6,051,648.75 were paid, leaving a surplus of $2,636,722.10. The total new construction which has been credited to capital account in this time is $6,524,588.84. A portion of this is represented in the surplus, but the major portion has been drawn from working capital, and the accounts and bills payable on June 30, 1904, accordingly amounted to $5,564,097.97. To liquidate this, and provide for further improvements, a loan of $7,000,000 has been provided for on two and three-year notes, secured by $10,000,000 of bonds, which are issued and put up as collateral. It has not been decided whether these bonds shall be ultimately sold to liquidate the notes, or whether they can be liquidated from future earnings.

Crucible Steel Company of America. — The report of this company for the year ended August 31, 1904, shows net earnings of $488,160.33, excluding substantially all the losses which the company charges were due to its subsidiary, the Clairton Steel Company. Under this name a complete steel plant was built and then sold, or practically given, to the United States Steel Corporation, at a loss set down by the Crucible management at about $4,000,000. The balance sheet shows a profit and loss item of $2,155,632.35 on the debit side, the Clairton operation having wiped out the surplus of $1,638,691.91 reported as of August 31, 1903, the net earnngs for the year, and left this much of a debit

besides. An issue of $7,000,000 of bonds has been authorized to re-finance the company's affairs.

United States Steel Corporation. — Net earnings for the third quarter of the current year are reported at $18,773,932, leaving, after all deductions for depreciation, bond-sinking funds and interest, and preferred stock dividend, a contribution to surplus of $1,312,988. Earnings for the nine months total $51,473,543, against $94,133,970 in the similar period in 1903 and $101,323,004 in the similar period in 1902.

STATISTICS

British Half-Yearly Iron and Steel Production. — From the "Iron and Coal Trades Review," the organ of the British Iron Trade Association, we compile the following summary of production of iron and steel in the first half of last year and this year, as gathered by the Association, and add for purposes of comparison the production for the whole of 1903, the figures referring to gross tons of 2,240 pounds:

	First half		Entire year
	1904	1903	1903
Total pig iron	4,048,965	4,378,998	8,811,204
Forge and foundry pig	1,850,463	2,096,313	3,875,826
Hematite pig	1,606,660	1,716,069	3,760,422
Basic pig	506,970	456,371	991,610
Spiegel, etc.	84,872	110,245	183,346
Total Bessemer steel ingots	865,683	911,670	1,910,018
Acid Bessemer steel ingots	553,071	560,634	1,316,915
Basic Bessemer steel ingots	312,612	351,036	593,103
Bessemer steel rails	523,771	483,964	1,061,441
Total open-hearth steel ingots	1,670,129	1,639,239	3,124,083
Acid open-hearth steel ingots	1,326,882	1,368,588	2,613,274
Basic open-hearth steel ingots	343,247	270,651	510,809
Total Bessemer and open-hearth	2,535,812	2,550,909	5,034,101

Throughout this comparison a decreased production is noted, with the striking exception of basic open-hearth steel, the increase in this comparatively minor industry being sufficient to cause a slight increase in the total make of open-hearth steel, and calling for an increased make of basic pig. The increase in basic open-hearth steel production of 72,596 tons in the first half of 1903 over the first half of 1902 is a continuation of the increase of 29,576 tons which that half-year showed over the first half of 1902, although in acid open-hearth there had been a decrease, and in Bessemer steel but a slight increase. The basic open-hearth steel industry is clearly growing in Great Britain, as it has been doing so markedly in the United States.

RECENT PUBLICATIONS

Analytical Chemistry. Vol. II, "Quantitative Analysis," by F. P. Treadwell; translated by W. T. Hall. 654 5½ × 9-in. pages; 96 illustrations. John Wiley and Sons. New York. 1904. Price, $4.00. — Students of Analytical Chemistry will welcome this translation of the second volume of Professor Treadwell's excellent work. It will be remembered that the first volume on qualitative analysis was translated by the same writer some time ago. The present translation has been made from the second German edition and includes a number of changes which Professor Treadwell intends to make in the third edition. Part I deals with the gravimetric determinations of the metals and the metalloids, Part II with volumetric analysis and Part III with gas analysis. Many useful tables are appended, including specific gravity tables, tension of water vapor, tables for calculating analyses, logarithms, and antilogarithms. It is always a pleasure to handle a book published by John Wiley and Sons, the printing, paper and binding being always so satisfactory in every respect.

A Systematic Handbook of Volumetric Analysis, by Francis Sutton; ninth edition; revised and enlarged. 617 5½ × 9-in. pages; 121 illustrations. P. Blakiston's Son & Co. Philadelphia, Pa. 1904. Price, $5.00. — This book is so well and favorably known by all analytical chemists as to call for little criticism on our part. The fact that it has reached its ninth edition is a conclusive evidence of its worth. The last edition is considerably enlarged, and the author treats its subject with authority and exhaustiveness. The book is well printed on good paper and attractively bound.

Treatise on Thermodynamics, by Dr. Max Planck; translated by Alexander Ogg. 272 4½ × 8½-in. pages; illustrated. Longsmans, Green and Co. London. 1903. Price, 7s. 6d. net. — This English translation of Dr. Planck's valuable book should be welcome by all English-speaking students of thermodynamics. The author rests his exposition of the subject upon the two

fundamental laws of thermodynamics, thus avoiding much which might be of a speculative character. His treatment is clear and logical and the reader, even if he be an advanced student, cannot fail to derive considerable instruction from Dr. Planck's book.

A Technological and Scientific Dictionary. Parts I, II, and III; edited by G. F. Goodchlid and C. F. Tweney. 192 6 × 10-in. pages. George Newnes, Ltd. London. Price, 1s. net, each part. — This dictionary will be completed in about 15 parts. It will define some 16,000 words used in building trades, Engineering, chemistry, physics, the textile industries, art, archeology, architecture and music. The definitions are necessarily concise and so worded as to appeal to the general reader rather than to the specialist. The usefulness of such a publication will not fail to be appreciated.

Transactions of the Institution of Mining and Metallurgy. Volume XI; Parts I and II, "Winding Plants for Great Depths," by Hans C. Behr; with discussions. Part I contains 444 4½ × 8½-in. pages of text and Part II 79 plates. Published by the Institution. London. Price, $10.00. — The secretary states in his preface that in the presentation of the present volume, which is devoted solely to Mr. Hans C. Behr's paper on "Winding Plants for Great Depths," the institution of Mining and Metallurgy received the coöperation of the South African Association of Engineers, and that the volume will form part of the "Proceedings" of both societies. A perusal of this volume shows that Mr. Behr's paper, which occupies 58 pages, called for a discussion amounting with the author's reply to 376 pages, a conclusive evidence of the interest with which it was received.

Self-Propelled Vehicles. A practical treatise on the theory, construction, operation, care and management of all forms of automobiles, by James E. Herman. 652 4½ × 8-in. pages; 461 illustrations. Theo. Audel and Co. New York. 1904. Price, $2.00. — The following extract from the author's preface explains the nature of the book: "For the practical information of such persons as have neither the time nor inclination to delve deeper into the subtleties of mechanics than the construction and management of their own machine requires, this book has been planned." The book is well printed and illustrated and attractively bound with gilt top.

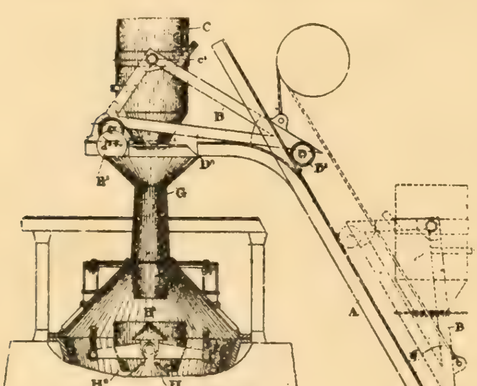
PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

768,201 and 768,202. Leading-Spindle and Coupling for Rolling Mills. — Maximilian M. Suppes, Elyria, Ohio. In a rolling mill, driving mechanism, the combination of a driving shaft or gudgeon, a driven shaft or gudgeon, a coupling rigidly secured to the driving shaft or gudgeon, a leading spindle having an exteriorly-fluted portion entering the said coupling and engaging interior flutes thereof, said coupling also having a clearance space to permit abnormal endwise movement of the spindle.

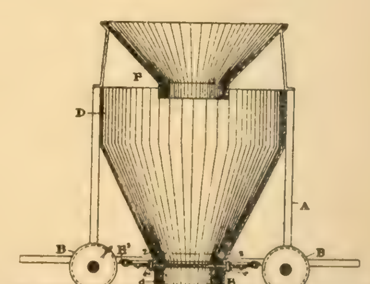
768,207. Blast-Furnace Top and Charging Device. — Samuel W. Vaughen and James B. McClure, Lorain, and Arthur J. Boynton, Elyria, Ohio. In a blast-furnace top, a receiving hopper having a centrally and horizontally opening discharge valve or diaphragm formed in three or more sections.



768,208.

768,208. Skip-Car or Hoist for Blast-Furnaces. — Samuel W. Vaughen and James B. McClure, Lorain, and Arthur J. Boynton, Elyria, Ohio. A skip-car, consisting of a wheeled supporting frame or truck, and a bucket hung on trunnions on said frame or truck and having a centrally opening discharge valve at its bottom.

768,248. Stock-Collecting Car or Lorry. — Samuel W. Vaughen and James B. McClure, Lorain, and Arthur J. Boynton, Elyria, Ohio. A stock-collecting car or lorry having its bucket provided with a centrally discharging receiving hopper.



768,248

768,264. Process of Producing Composite Metal Plates. — Ferdinand E. Canda, New York, N. Y., assignor to Crome Steel Works, Chrome, N. J. A method of producing composite steel articles comprising alternate layers of steel of different melting-points, which consists in forming grooves in a surface of an article composed of steel of relatively low melting-point, and then casting molten metal of a grade

having a higher melting-point around such article and causing the molten metal to envelop the same to such an extent as to prevent extrusion of the steel of low melting-point upon working.

768,265. Method of Producing Open-Hearth Steel. — Hugo Carlson, Sydney, Canada, assignor of one-half to James H. LeFevre, Sydney, Canada. An improvement in the basic open-hearth process which consists in controlling the character of slag produced by adding to the other materials employed in said process a quantity of titaniferous ore suitable for said purpose.

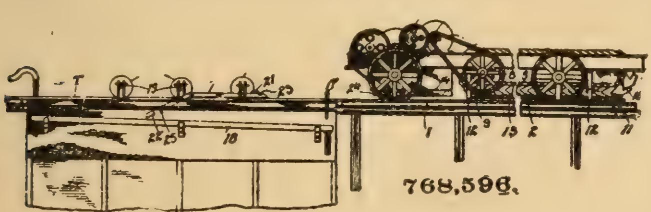
768,546. Tuyère Iron. — Loudon Silcott, Mount Vernon, Ohio. A tuyère iron comprising a cylinder having a blast opening, and a valve pivoted within the cylinder and comprising wings one at an angle to the other and both engaging the inner circumference of the cylinder in opening and closing the latter and the said blast opening.

768,551. Manufacture of Iron and Steel and Their Alloys. — José B. de Alzugaray, Bromley, England. In the process of manufacturing iron and steel and their alloys, producing refined pig iron by mixing pulverized ore with pulverized carbon in excess of that required for reduction and an alkaline substance and water, adding thereto a mixture of a fluoride and a chloride, forming fluxing and refining agents, compressing the mixture into bricks and subjecting the bricks to the action of heat in any well-known manner as described.

768,552. Manufacture of Iron and Steel and Their Alloys. — José B. de Alzugaray, Bromley, England. The process of manufacturing iron and steel and their alloys and consisting in mixing pulverized ore with a binding material, a mixture of a fluoride and a chloride adapted to act as both fluxing and refining agents to produce a non-carburized material, compressing the same into bricks, and fusing these bricks together with pig iron and scrap.

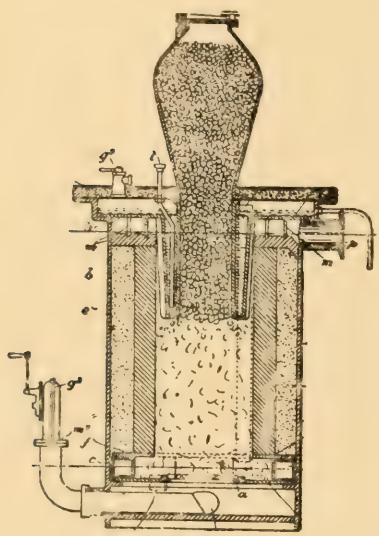
768,553. Manufacture of Iron and Steel and Their Alloys. — José B. de Alzugaray, Bromley, England. The process of manufacturing iron and steel and their alloys from the ore and consisting in mixing pulverized ore with carbon in excess of that required for reduction and a flux and refining agent to produce a carburized material, compressing the same into bricks and fusing these bricks with similar bricks of a non-carburized material composed of ore, a binding material, a flux and a refining agent.

768,596. Furnace Charger. — William H. Freeland, Ducktown, Tenn. In a furnace charger, the combination with a furnace having a charging opening, of a movable cover normally closing said opening, a traveling conveyor adapted to dislodge the cover and discharge its contents into said opening, and means for moving the conveyer along the opening to distribute the charge.



768,596.

768,576. Heating Furnace. — James W. Arnold, Covington, Ky. In a heating furnace for iron and steel, an automatically-operated charging door located in the crown of the furnace, a hearth section of substantially the area of the charging door, located beneath the door and adapted to withstand without injury the impact of the charged metal, other hearth sections adjacent to said first-named section, and a door for removing the heated metal.


768,655.

768,655. Gas Producer. — William J. Crossley and Thomas Rigby, Manchester, England. In combination, a steam chamber, a fire grate, a primary air supply for the producer, a secondary air supply passing through the steam chamber so as to vary the proportion of steam to air corresponding to the load and means for delivering the primary air and secondary air and steam to the under side of the fire grate so that they will mix and enter the fire together.

768,858. Charging Apparatus for Blast-Furnaces. — Walter Kennedy, Allegheny, Pa. A blast-furnace plant having in combination a skipway, a skip movable along such way, a storage bin arranged above the skipway at the skip-loading point, a line of track extending from the ore pile to a point above the storage bin, and cars movable along such track.

768,972. Combined Crucible and Preheater. — James A. Aupperle, Indianapolis, Ind. The combination of a crucible provided with an air-induct and an air-educt, a preheater connected with said air induct, and means for heating both said crucible and said preheater.

769,052. Apparatus or Furnace for Hardening Steel Cutters or Other Tools. — Shipley N. Brayshaw, Manchester, England. Apparatus for hardening steel cutters and other tools comprising in its construction an annular casing with inwardly-projecting sides, a melt-pot therein wholly inclosed by the casing to contain a fusible mixture, a perforated tray inside the furnace to hold the tools and lower them into the pot, a pedestal of fire-brick upon which the pot rests and against which the flame impinges and a ring of burners placed round the bottom of the furnace.

769,106. Mud-Gun for Filling Iron Notches of Blast-Furnaces. — Felix McCarthy, Pottstown, Pa. In a mud-gun of the character specified, a mud or clay chamber having a discharging orifice; a piston adapted to discharge the mud therefrom and a steam cylinder having a piston-rod connected to said mud-piston and adapted to actuate the same, in combination with a mud-valve of suitable character located intermediate the mud receptacle and discharging nozzle thereof.

769,121. Welding Machine. — George B. Walker, Lemoyne, Pa., assignor of three-fourths to Jacob E. Hertzler, Mechanicsburg, Pa., Robert

L. Myers, Camphill, Pa., and William J. Lescure, Harrisburg, Pa. In a welding machine, the combination of an anvil with a die for holding and shaping the interior surface of the welded end of a link, means for locking the die to said anvil, an arm pivoted to the anvil, a tool-support pivoted to the upper end of said arm, a reciprocable tool carried by said support, and a reciprocable die carried by said tool provided with a lower inclined surface having a cavity in the forward portion of its face and constructed and designed to contact the upper face of the stationary die in its downward movement and to then slide or glance toward the forward portion of the stationary die to weld the link and form the exterior surface of the welded end of the link.

769,322. Foundry System. — George W. Packer, Chicago, Ill. In a foundry system, the combination of a series of mold carriers, means for advancing said carriers intermittently, a mold clamp provided with a pouring aperture, and means for actuating said clamp to engage the molds as the carriers successively arrive at the clamp.

769,364. Pyrometer. — Henry M. Tory and Howard T. Barnes, Montreal, Canada. In an instrument for measuring temperature the combination of a pyrometer containing a coil and loop; a calibrated contact and a second contact adapted to be brought into electrical connection with same; a normally open main electric circuit having its terminals connected to said contacts and forming two paths which respectively include the coil and loop of said pyrometer; a resistance-coil located in each of said paths; a supplemental resistance-coil in one of said paths; and a telephone-circuit connected with said main circuit.

769,603. Manufacture of Iron or Steel Wire. — Fredrik Forsberg, Sandviken, Sweden. An improvement in the art of forming wire from a rod of iron or steel, which consists in first heating said rod, and then, while it is hot, subjecting it to alternate rolling and roll-drawing operations simultaneously applied at different parts of the rod.

769,709. Tube-Rolling Mill. — John H. Nicholson, Pittsburg, Pa., assignor, by mesne assignments, to National Tube Company, a Corporation of New Jersey. In a tube-rolling mill, a mandrel-bar, a plurality of supports for the mandrel-bar located intermediate its ends and spaced away from each other, each of the supports having an aperture adapted to pass the mandrel-bar and a tube rolled thereon, and means within the supports normally engaging the mandrel-bar and movable out of the aperture and through the aperture in the adjacent support by the thrust of the tube thereagainst.

769,712. Tilting Metallurgical Furnace. — John A. Potter, Pittsburg, Pa. An endwise tilting furnace, movable regenerators located at opposite ends of the furnace and having ports arranged to register with its end ports and arranged with a space below one end of the furnace to admit a receptacle and means for tilting the furnace below the ports to pour at least a part of the bath from the end port of the furnace into the receptacle.

770,025. Furnace. — Theodore G. Selleck, Chicago, Ill., assignor to Acme Steel Company, Chicago, Ill., a corporation of Illinois. A furnace

provided with a treating box opening through one wall of the furnace a combustion chamber arranged directly under one end of the treating-box and flues so arranged as to conduct the flames from the combustion chamber forwardly under the treating box, thence upwardly around the box adjacent to its forward end, and thence backwardly and across the top and along the sides of the box.

770,111. Apparatus for Charging Blast-Furnaces. — Walter R. Reece, Pittsburg, Pa., assignor, by mesne assignments, to Clarence W. Coffman, Pittsburg, Pa. This apparatus comprises a casing having curved walls and two-axially-mounted valves movable toward each other, each valve fitting against the said curved walls and having a plurality of pockets, opposite coinciding portions of the two valves forming the bottoms of coinciding pockets, a bell beneath said valves, and an actuating rod therefor, said valves being designed to discharge against the apex of said bell.

770,624. Gas Producer. — Walter O. Emsler, Pittsburg, Pa., assignor to The Emsler Engineering Company, Pittsburg, Pa. Combination, with the combustion chamber, of a water-sealed trough below the combustion chamber, a centrally-disposed cylindrical casing extending upwardly from the bottom of the trough, and a series of gratings supported by the cylindrical casing arranged in the form of a hollow frustrum of a cone.

GREAT BRITAIN

218 of 1904. Slag Cement. — C. von Forell, Hamburg, Germany. Making a cement from slag by powdering the slag, then heating it in an oxidizing flame to just below the point of fusion, and then quenching.

7,694 of 1904. Cupola. — T. Holland, Delphos, Ohio, U. S. A. In cupolas for melting metals, improved means for introducing hot-air blasts to maintain the heat of the metal.

4,975 of 1904. Treating Iron Sands. — M. Moore and T. J. Heskett, Melbourne, Australia. Process consists of acting on the fine sands by carbonic oxide and passing the reduced iron into a gas furnace to be melted.

21,183 of 1903. Briquette Furnace Attachment. — W. Simpkin, London. Improved arrangement of the heating apparatus for furnaces used in baking briquettes of ore.

21,299 of 1903. Steel Treatment. — C. C. Garrard, Hollmwood. Electrolytic method of removing scale from forged steel.

The Iron and Steel Magazine

*". . . . . . Je veux au mond publier
d'une plume de fer sur un papier d'acier."*

Vol. VIII | December, 1904 | No. 6

RECENT DEVELOPMENTS IN GAS ENGINES*

Written for The Iron and Steel Magazine

THE developments which have taken place during the last four or five years in fuel saving are of absorbing interest to the engineer. In the manufacture of coke the by-product oven saves the valuable gas which has heretofore generally been wasted; and the gas engine has been developed to use this gas as well as to use blast-furnace and producer gas.

In speaking of gas engines reference is particularly had to the large German and other European designs that are so successfully running abroad to-day. It is true that there have been a number of gas engines built in this country for a great many years back, and while these have had more or less success, they have been almost entirely confined to small unit sizes; and their application has been much limited by the restricted conditions under which they would successfully operate. To-day, however, in Germany, many large installations of gas engines can be seen that seem to be, in regard to shut downs, repairs, and other operating features, as satisfactory as steam engines. An idea of the size of these engines can be had when they drive blowing cylinders of 80″ diameter by 60″ stroke, and deliver 30,000 cubic feet of free air per minute to 25 pounds per square inch pres-

* Received, October 18, 1904.

sure. The gas engine is also much used in electrical work, but so far, very little in rolling mill work. The only large installation at present in this country is in Buffalo, N. Y., at the plant of the Lackawanna Steel Company; where some 40,000 horse power of gas engines are to operate on blast-furnace gas. Furthermore, as several of our largest engine builders are now putting on the market gas engines as well as steam engines, it would lead one to believe that we are to see great changes and developments in this direction in the next ten or fifteen years.

Nearly all the designs at present which are available for commercial purposes have originated in Germany. And really it is natural that this should be so, for until recently fuel in America, especially in the steel plants of the middle states, was hardly considered at all. A very excellent illustration of this is the way natural gas was used and wasted a few years ago. In Germany fuel is high and labor cheap, just the reverse of America, and it is reasonable they should be inventors of fuel savers, while we are inventors of labor savers.

We all know what a high mathematical efficiency the gas engine has; and also that the cooling water, used to keep down the excessive temperatures that would otherwise prevent proper working, carries away so much heat that this efficiency is nearly cut in half. Furthermore, useful heat is thrown away in the exhaust, but notwithstanding these and many other losses, the gas engine in practice ought to develop 25 per cent efficiency. Many tests show more than this, but it seems safe to say that with the ordinary working losses we may expect 25 per cent. As a comparison, it is doubtful if a compound steam engine in practice will do better than 12 per cent or 13 per cent efficiency. A boiler and furnace that gives 70 per cent efficiency is a very good one, and combining this with the steam engine we have a total efficiency of less than 10 per cent against the gas engine's 25 per cent. The above case is applicable to blast-furnace work, where the common practice is now to burn the blast-furnace gas under steam boilers; or the case is a comparison where natural gas is used under boilers for generating steam. If gas is generated from coal in a gas producer the efficiency of the gas producer must be taken into account; but even with this we may safely say that we can save at least one-half of our fuel by the use of a gas engine. Some articles have been published stating

that the gas engine on blast-furnace gas would use for the same work only one-fifth or one-sixth the gas required by steam boiler and engine. Most of these articles, however, have been either based on figured results or on exceptional tests, and the conservative engineer will doubt if such enormous savings can be effected working day after day in actual practice. It must be remembered that the efficiency of the gas engine falls off as the load carried is diminished, and that during a test favorable and constant loads are often more convenient to measure.

In connection with blast-furnaces, the first cost of a gas engine plant either for blowing or generating electricity is somewhere about one-half more than a steam boiler and engine plant; but even with the interest on money invested, depreciation, maintenance, etc., there still seems quite a saving in favor of the gas engine.

Blast-furnace, coke oven, producer, natural gas, and several others are used in gas engines. Anthracite or coke makes a satisfactory gas in a producer, but in the case of coke, of course, part of the heat in the coal is lost in making coke, and it is not an economical fuel. The blast-furnace being really a coke-gas producer, gives a very desirable gas, and although it varies in richness, it does not do so the way a producer does. The engines are adjusted to run on a certain richness, and for economical working a reservoir or many producers working together should be used. An entirely satisfactory gas producer using bituminous coal is not yet on the market. One or two come near being so, but there are several objectionable features; the complication of washing the gas and of selling a by-product, which is not always expedient; and small plants of such design are expensive and undesirable. Some of the producer manufacturers claim in connection with gas engines to produce a brake horse-power per pound of bituminous slack coal, and no doubt when a satisfactory producer is to be had it will be economy to install gas engines in many places where boilers and steam engines are now used. The Loomis (see Fig. 1) is one of several types of gas producers that use a combination of water and producer gas. The Mond and Duff seem to be giving such results in practice that we certainly may expect a simple and efficient producer of this kind before long. In Germany a bituminous coal gas producer exploited by Paul Schmidt is reported as giving satisfactory

results, although I have never seen one. In this country the Morgan Construction Company of Worcester are working on this and the outlook is very promising.

A good gas for gas engines must not have too much hydrogen in it, otherwise the gas becomes "touchy," and there is

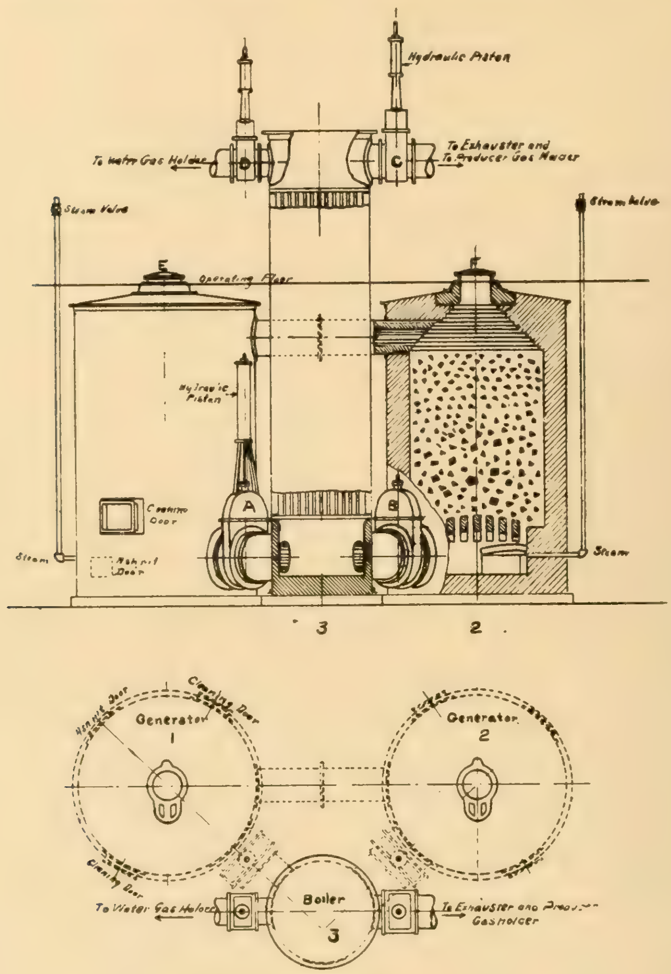


Fig. 1. The Loomis Gas Producer.

danger of explosions at the wrong time. Another and a very important point is to keep the gas free from dust. A gas engine will take care of a certain amount of dust for a limited time, but if too much, it cakes and bakes on the cylinder walls, and with the high temperatures from the working mixtures, soon gets into an incandescent state, and of course ignites the charge prematurely. It is evident that this is almost the key of the situation; and the idea has been prevalent that the German blast-fur-

nace gas carried much less dust than ours. The older German, like the English furnaces, gave a limited output, whereas if these same furnaces were in America they would be pushed to the limit, much more air used at a higher pressure, and probably more dust would be carried in the gas given off. However, most of the later German furnaces, and especially those where gas engines have been introduced, are following the American practice. At Meiderich, where there is a gas engine installation, there are three blast-furnaces giving an output of about 350 tons each per 24 hours, with dust running about 45 tons per furnace per 24 hours. It may be said also that gas engines are working satis-

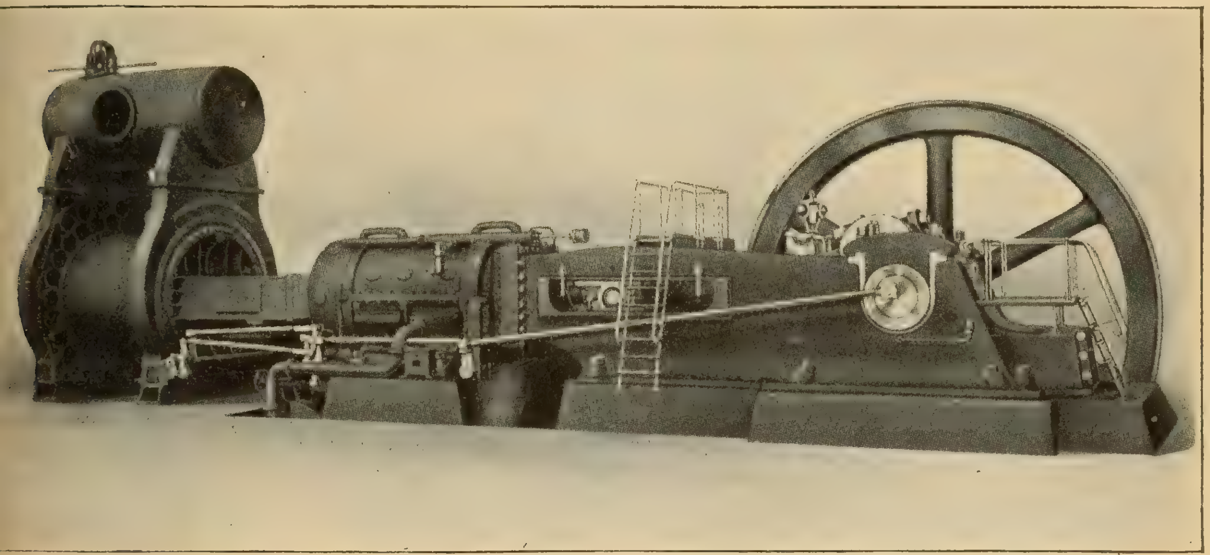


Fig. 2. Cockerill Blast-Furnace Gas Blowing Engine.

factorily where blast-furnaces are fed with ore from the Luxemburg district which is extremely soft and very dusty.

There are several ways of cleaning the gas, but the most general is by use of the centrifugal principle. Usually an ordinary fan blower some five feet in diameter is used, and the incoming gas is piped so as to be delivered at the center of the fan. Water is sprayed into the fan with the gas, and the particles of water and dust are thrown by centrifugal force against the outer casing of the fan and drain to the bottom, being removed by a water seal. It may be said that at one plant, where 65 per cent of the furnace charge is made up of the fine Mesaba ore, that the gas delivered to the engines is cleaner than the air from the engine room with which it is mixed. It is of interest to note that

gas for whatever purpose used should be cleaned. The present way of burning gas which is full of dust is about equivalent to efforts to obtain the best economy from coal when it is full of slate or other dirt.

The two and the four cycle types of gas engines seem to be equally popular at present. The Cockerill and Nuremberg engines are good examples of the four cycle type. (See Figs. 2, 3, 4 and 5).

The Körtung (Fig. 6) engine is an example of a two cycle engine, and can best be understood from the sections. The engine is double acting like a steam engine, and gives two impulses every revolution. No exhaust valves are necessary, as the piston uncovers the slots shown in the center of the cylinder. Two pumps can be seen on the side, one for air and one for gas, both compress-

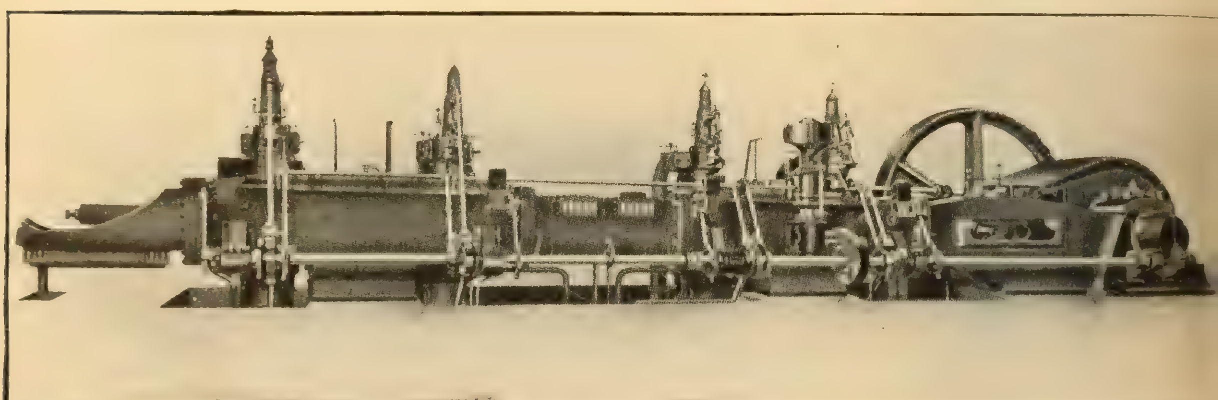


Fig. 3. 500 H. P. Tandem Double Acting Cockerill Gas Engine.
The Wellman, Seaver, Morgan Company, Cleveland, Ohio.

ing to about nine pounds per square inch. It will be understood that the instant the piston with the charge already exploded begins to uncover the exhaust ports, the air from the pump is admitted, and cleans or scavenges the cylinder of the burnt gases.

The method of operation is as follows:

(1) Charge exploded, piston started on forward stroke.

(2) Near end of forward stroke exhaust ports are uncovered, valves open and admit scavenging air, which cleans cylinder of burnt gases by time exhaust ports are again covered on return stroke.

(3) Fresh charge mixture of gas and air comes in behind scavenging air and is caught by

(4) Valves closing; and piston compresses charge ready for next explosion.

Ignition is caused by a spark in the cylinder from ordinary spark coils. The cylinder and piston are both water jacketed, as can be seen in the sketch. The water for the piston enters at the cross-head pin, the piston rod having two holes in it, thus allowing the water to flow in one and out the other. Regulation is so close that electric alternators can be run in parallel. The old hit and miss principle of governing has been abandoned by all the large gas engine builders.

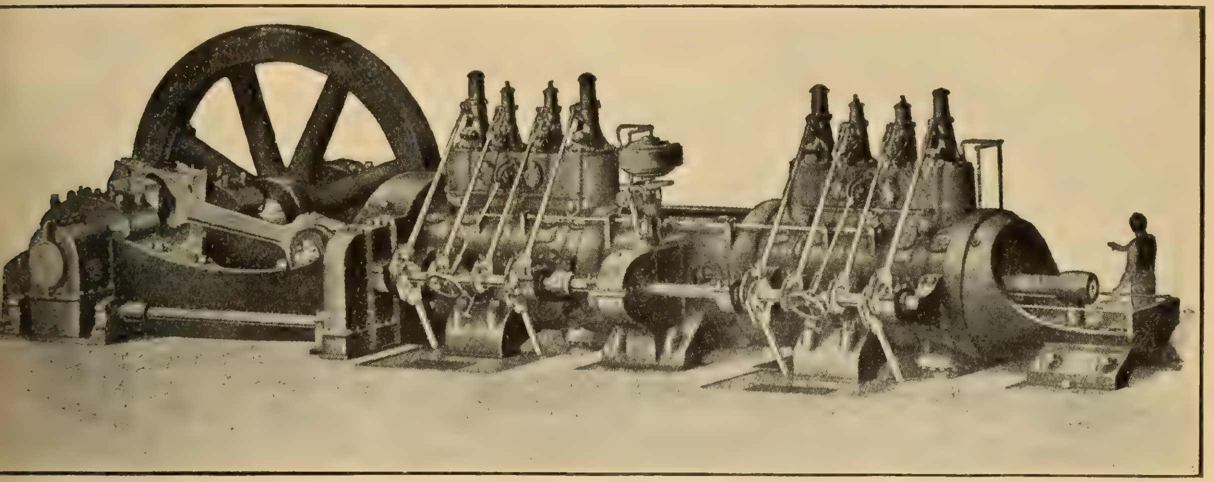


Fig. 4. Nuremberg Gas Engine.

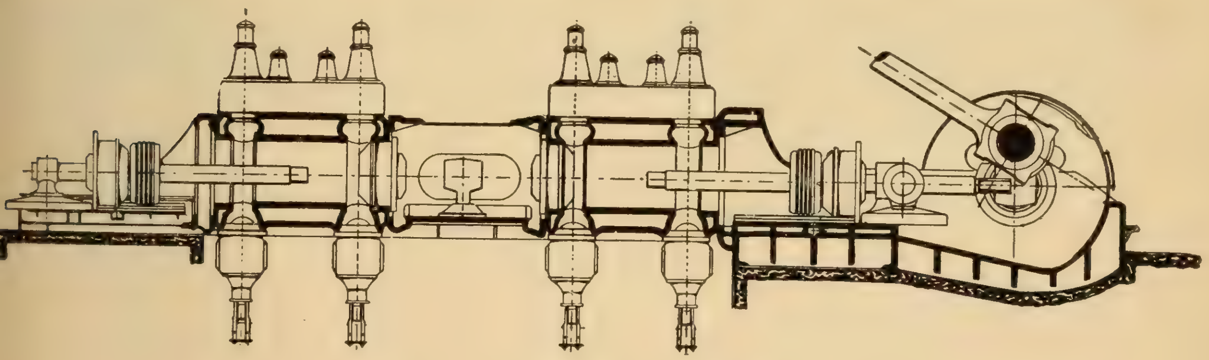


Fig. 5. Nuremberg Gas Engine.

The Nuremberg engine (Figs. 4 and 5) is an example of a four cycle engine, has two cylinders in tandem; this arrangement being equivalent in power developed to the single cylinder of the Körtung engine. There are here also, as in the Körtung, two explosions for one revolution of the engine; but in each cylinder there is one explosion only for four strokes as follows:

(1) Charge exploded and piston travels to end of forward stroke.

(2) Exhaust valve opens and remains so during return stroke of piston, thus cleaning cylinder of burnt gases.

(3) Air and gas valves open, and piston on second forward stroke sucks in charge.

(4) All valves closed and charge is compressed during return stroke.

Here with the tandem arrangement, as each cylinder is double acting, we get, as above stated, two impulses every revolution, so the crank pin will practically be the same size as in the Körting engine.

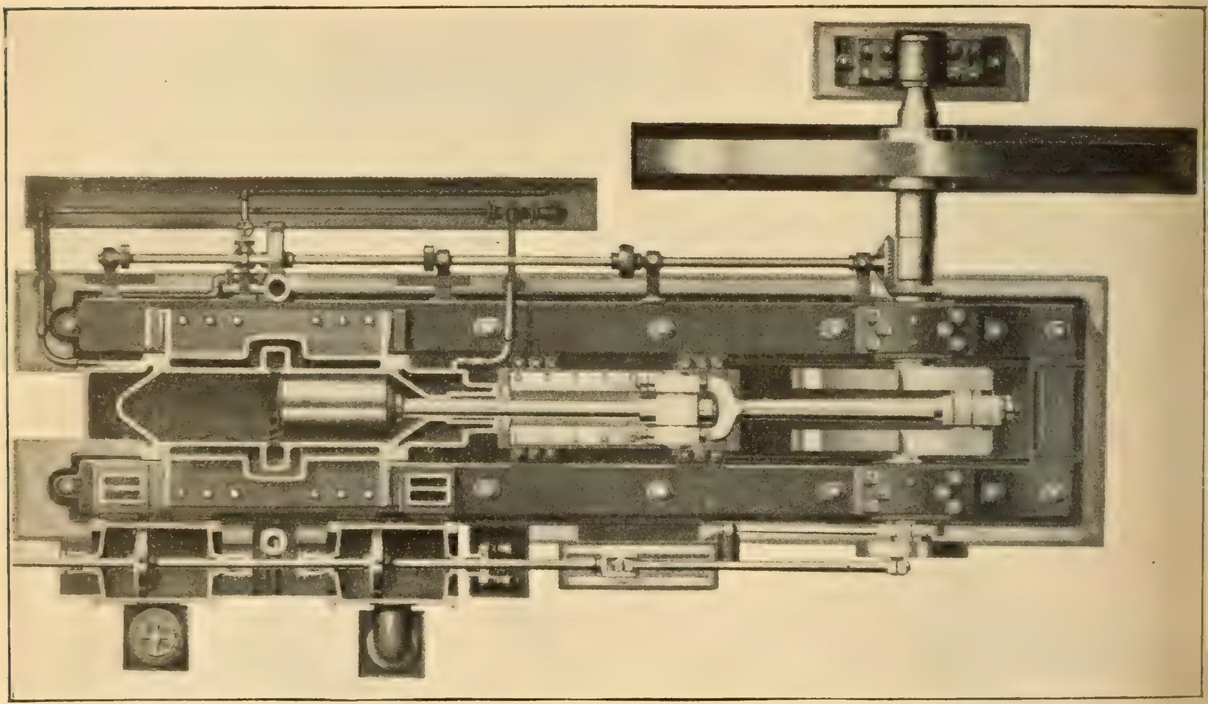


Fig. 6. The Körtung Gas Engine.

A rather curious engine which has had some success in Germany is the Oechelhäuser. (Fig. 7.) This engine has been running since 1898. The principle of the construction consists of the symmetrical arrangement of two pistons working toward each other in a simple cylinder, which is open at both ends. A plan of the engine and section of the cylinder is shown. By reason of the two moving pistons no valves are necessary, the ports in the cylinder being uncovered at the proper times. The engine is two cycle, and like the Körting, must be provided with an air pump for cleaning the cylinder with fresh air.

The competition at present between the two and four cycle engines can only be settled by long use in practice. The two cycle is more compact, but although it has only one working cylinder, it has in addition large gas and air pump cylinders to be taken care of, which, of course, the four cycle does not have. The four cycle people say regarding the efficiency of the two cycle engine, that it is impossible to displace instantaneously the burnt charge by the scavenging air, and that more or less mixture of gas, air and burnt gases, and losses through valves will

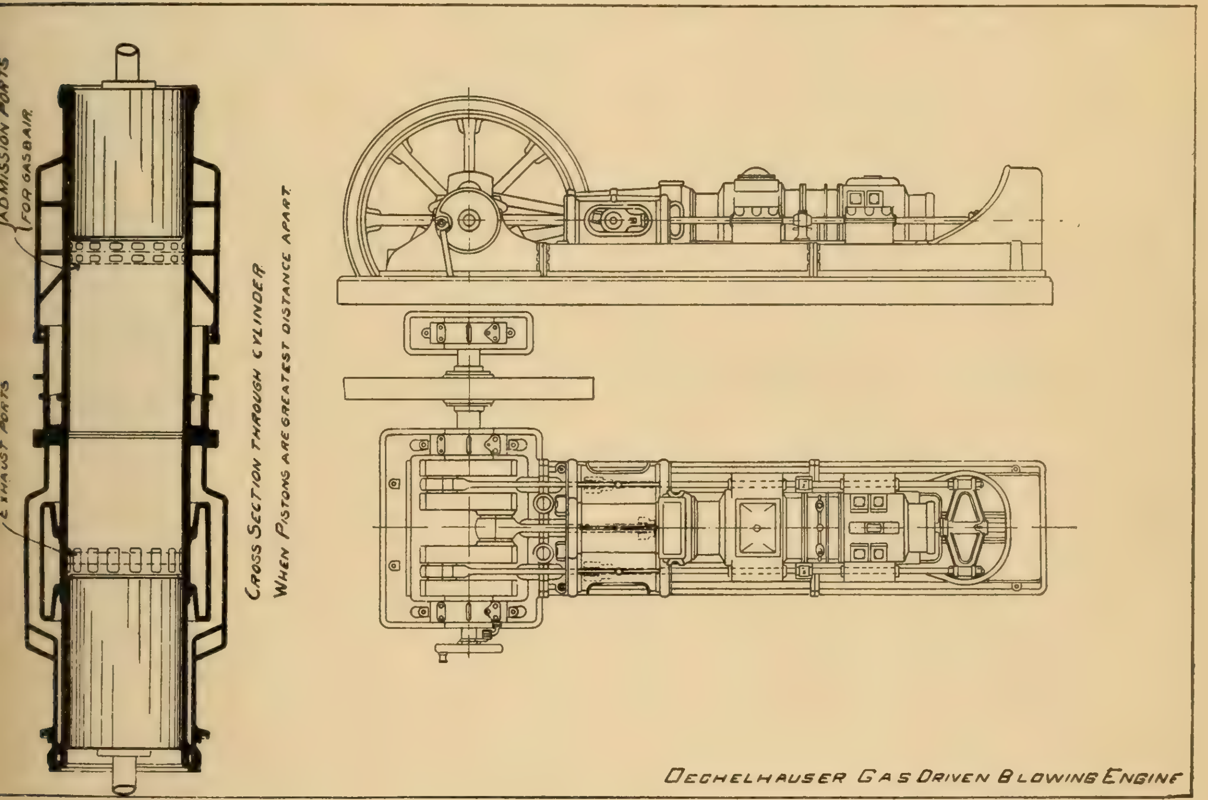


Fig. 7. The Oechelhauser Gas Blowing Engine.

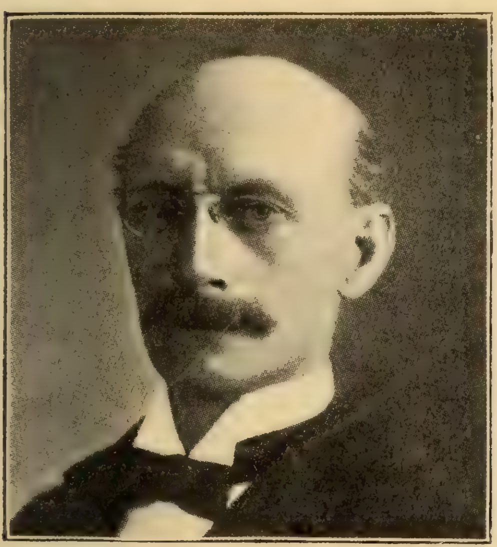
take place. It is of course difficult to keep a layer of air with gas behind it without mixing, and for this reason the diameter of the two cycle engine is probably limited as to size; too large a diameter giving too much freedom. This means with engines of large power several cylinders will have to be used; but in ordinary sizes the first cost of the two and four cycle types are not very different. The four cycle being a longer engine than the two, the expansion of its parts is harder to take care of.

The gas engine, unlike the steam engine, gives maximum

efficiency at maximum load. It is advisable, therefore, from a point of economy in gas consumption to run a gas engine with all the load it will carry. This may have induced the old gas engine builders to rate the engines as high as possible, and this is perhaps one reason why the gas engine has failed to meet the demands of the industrial world, for it does not possess sufficient margin of power. It is interesting to see how in blowing cylinders connected to gas engine cylinders the range of pressure is sometimes taken care of. Suppose the gas engine is designed to give an air pressure of 20 pounds per square inch when working at full capacity, and now suppose we desire a pressure of 30 pounds for a short time to help the working of a blast-furnace. We might have installed an engine which would give 20 pounds when working at, say, half its full load, but not only would this be expensive in gas consumption, but also in first cost of installation. Blowing cylinders are made with a valve arranged so that when excess pressure is wanted this valve allows the piston to pump into the atmosphere for the first portion of the stroke. It then closes, and the extra speed and impetus which the piston has gained brings the pressure up. Of course, the volume and weight of air pumped falls off, but it is stated that double the normal air pressure can be obtained in this way.

THE APPLICATION OF DRY-AIR BLAST TO THE MANUFACTURE OF IRON *

By JAMES GAYLEY



THE atmosphere, which plays such an important part in the manufacture of iron and steel, is the most variable element to contend with in its several processes; and particularly is this true of the blast-furnace process, which consumes air in large quantities. At no time since the blast-furnace became an important and widely used apparatus — even when it was operated in the most crude manner — have the variations in composition of the raw materials used been as frequent and as great as the variations in humidity of the atmosphere. Great and important improvements have been made in the blast-furnace and its accessories, as in the hot-blast stoves, the increase in size and change in the shape of the furnace, more efficient blowing engines, the increased protection given to the bosh walls, and in the careful preparation of the raw material, all of which have exerted a pronounced influence on the furnace operations from a metallurgical standpoint. During the past eight years but little advance has been made in this direction; the fuel consumption has not diminished, nor has there been any material increase in production. Within this period, however, there has been witnessed the greatest development in appliances for the economical handling of material, and so complete has been the work in this direction, that, except in isolated cases, in this country at least, a further extension does not hold out much promise of a satisfactory return on the investment required. It seemed that, with the exception of the gas engine, we had about reached the limit, for like a strong wall the atmosphere,

* The Iron and Steel Institute, New York meeting, October, 1904.

with its humidity as variable to-day as when first blown into a primitive blast-furnace, appeared to stand as a barrier to further progress. In furnaces using ore from the Lake Superior district the raw material, amounting to about 7,200 pounds per ton of iron, varies in composition within ten per cent and is as uniform as human skill can make it; but the atmosphere, of which 11,700 pounds are consumed per ton of iron, varies in its content of moisture from 20 to 100 per cent, from day to day and often in the same day, thus rendering the process, even with the best appliances, an uncertain one and dependent on the caprice of the atmosphere.

The desiccation of the air used in blast-furnaces to such extent as to cause a practical elimination of the moisture, or its reduction to a small quantity, and maintaining it uniform, must of necessity contribute in a very marked degree toward the attainment of uniformity in the furnace operations, and the advantages from desiccation can be appreciated only after due consideration is given to the volume of air that is consumed per minute and the large amount of moisture which it contains. Managers of blast-furnaces are familiar with the chilling effects produced in the hearth by a tuyère that is leaking, which immediately results in a deterioration in the grade of the iron, and yet the quantity of water ordinarily entering the furnace under these conditions is not greatly in excess of the quantity carried in, like a steady stream, by the atmosphere, during a period of the average humid conditions prevailing in the summer season in this country.

It has been deemed preferable in this communication to express the quantity of moisture contained in the atmosphere, as grains of water per cubic foot of air, inasmuch as the quantity of air blown into blast-furnaces is expressed in cubic feet. With air containing one grain of water per cubic foot, there is passed into the furnace, for each 1,000 cubic feet used per minute, practically one gallon of water per hour. The furnaces of average size in the Pittsburg district consume about 40,000 cubic feet of air per minute, which would pass into the furnace 40 gallons of water per hour for each grain of moisture contained in a cubic foot of air. The quantity of moisture in the air, taken from daily readings by the observer of the United States Weather Bureau at Pittsburg, is set forth in Exhibit I.

Exhibit I

	Average Temperature	Grains of Water per Cu. Ft. of Air	Gallons of Water Entering per Hour into a Furnace Using 40,000 Cu. Ft. Air per Minute
January	37.	2.18	87.2
February	31.7	1.83	73.2
March	47.	3.4	136.
April	51.	3.0	120.
May	61.6	4.8	192.
June	71.6	5.94	237.6
July	76.2	5.6	224.
August	73.6	5.16	206.4
September	70.4	5.68	227.2
October	56.4	4.0	160.
November	40.4	2.35	94.
December	36.6	2.25	90.

The above exhibit, like all records made by the Weather Bureau, is from observations taken on the top of a high building, and does not correctly indicate the condition of the atmosphere at the furnaces where the air is used. In fact, at one of the steel works in Pittsburg, observations made simultaneously at three separate stations showed quite a little variation in moisture. For the purpose of comparison with observations of the Weather Bureau, there is shown in Exhibit II the average monthly content of moisture in the air at the furnaces, the observations being made at 9 A. M.

Exhibit II

	Grains of Water per Cu. Ft. of Air
January	2.8
February	2.7
March	3.1
April	3.3
May	4.7
June	7.3
July	7.0
August	7.1
September	5.4
October	3.2
November	3.3
December	3.0

The variations in moisture from month to month set forth clearly the conditions, as to atmosphere, with which blast-fur-

Note. — All tons are gross tons of 2,240 pounds, and all temperatures are Fahrenheit.

naces in this country have had to contend. If these conditions were uniform throughout the whole month, it would not be a difficult problem to deal with; but unfortunately they are not uniform, and it is instructive to note the changes which occur from day to day in the same month. In Exhibit III is shown a record worked out from data furnished by the Pittsburg Weather Bureau. These observations represent a different period from that shown in Exhibit I; they were taken at 8 A. M. and 8 P. M., and show the grains of water per cubic foot of air at the time observed, for the months of January and July.

Exhibit III

	January Grains of Water		July Grains of Water	
Day.	8 A. M.	8 P. M.	8 A. M.	8 P. M.
1	1.96	3.06	7.24	7.48
2	2.55	3.66	8.23	7.98
3	2.46	3.80	8.50	7.48
4	2.07	2.27	8.50	7.48
5	1.81	1.12	8.46	7.72
6	.99	1.12	6.50	8.24
7	1.16	1.67	8.78	7.47
8	1.49	1.88	7.98	7.24
9	1.96	2.19	6.78	5.94
10	1.81	1.88	7.48	6.35
11	1.74	1.55	7.98	7.48
12	1.55	1.07	6.73	6.35
13	.99	1.55	5.94	4.84
14	1.61	1.81	5.55	5.74
15	1.67	1.96	5.74	5.19
16	2.04	2.27	6.35	6.35
17	2.45	3.29	7.72	7.98
18	1.81	1.32	7.24	7.24
19	1.12	1.16	8.24	7.48
20	1.43	2.11	7.48	7.24
21	2.11	1.88	7.72	7.38
22	1.88	1.88	6.78	5.74
23	.91	1.17	7.43	6.35
24	.99	2.11	6.56	6.11
25	.69	1.83	6.05	7.74
26	.61	.99	7.72	7.32
27	.56	.88	7.98	7.48
28	.72	.70	6.56	5.74
29	.76	.80	6.14	5.01
30	.95	1.12	5.74	6.35
31	.70	1.41	6.56	5.19

It will be observed in the preceding exhibit that, while the

moisture in the atmosphere in the month of January is much less than in July, yet the percentage of variation is greater. In order to illustrate more precisely the exact conditions with respect to the atmosphere, under which blast-furnaces must be operated, there is shown in Exhibits IV and V a record of observations taken each hour of the day, and in order not to make the data too burdensome the months of April and October have been selected, as they represent the months between the warm and cold seasons, and will also serve for comparison with January and July, as shown in Exhibit III.

It should be stated, with reference to the Exhibits IV and V, that observations were taken with a stationary instrument, which shows results somewhat higher, and not as accurate as those taken with a whirled psychrometer. Nevertheless, they were taken with the same instrument and are relatively correct. By simply multiplying the grains of moisture by 40 — which represents the number of gallons of water entering a modern furnace per hour, for a content of one grain of moisture in a cubic foot of air — a clear idea can be had of the gallons of water entering the furnace per hour, for the various conditions of humidity. The changes are great not only from day to day, but from hour to hour in the same day, and often they are very abrupt. These records were made at a furnace plant, located on the bank of a river, where the conditions exist for an increase in humidity as compared with higher ground; and to what extent the abrupt changes may have been caused by the presence of steam in the atmosphere — absorbed from spraying of the hot pig beds, the blow-off from boilers and exhaust from engines, or from a rain-storm when the humidity decreases suddenly — it is impossible to say. How frequently has it happened, in the experience of every furnace manager, that the furnace has gradually or suddenly lost its hearth temperature and produced a grade of iron either undesirable or unmarketable, without any visible cause. Tuyères are examined for leaks, the raw material in the stock-yard is carefully inspected, and usually the coke is condemned. A more intimate acquaintance with the atmosphere would have provided a correct and ready reason, for the variations therein are not only many times greater than in the raw material, but a greater weight of it is used per ton of iron.

Exhibit IV

April	A.M.							P.M.												A.M.				
	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
1	2.77	3.30	3.71	3.71	3.09	3.46	3.46	3.46	3.46	3.46	3.46	4.11	3.71	3.71	3.71	3.30	3.71	3.71	3.71	3.30	3.71	3.71	3.71	3.09
2	3.71	3.71	3.30	3.30	3.71	3.71	3.46	3.46	3.46	3.81	3.46	3.81	3.09	3.81	3.30	3.77	2.77	3.71	3.71	3.71	3.71	3.71	3.68	3.30
3	3.09	3.09	3.09	3.09	3.46	3.46	3.46	3.09	3.09	3.46	3.09	3.30	3.30	3.02	3.02	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30	3.30
4	3.71	3.71	3.71	3.71	3.71	4.11	4.11	4.67	4.67	3.81	3.81	4.11	3.30	4.01	3.30	3.71	4.01	3.71	3.71	3.30	3.38	3.30	3.30	4.01
5	3.68	3.68	4.01	3.30	4.01	3.89	3.71	4.11	4.11	3.46	4.11	4.11	4.11	3.46	3.09	3.09	3.09	2.47	2.77	2.77	2.77	2.77	2.77	2.77
6	2.47	3.09	3.09	3.09	3.71	3.71	3.71	3.71	3.46	3.46	3.71	3.71	3.71	3.71	3.71	3.71	3.09	3.30	3.30	3.30	2.77	2.77	2.77	2.47
7	2.77	3.30	3.30	2.77	4.01	3.30	3.71	3.81	4.11	4.33	4.67	4.67	4.11	4.01	3.30	3.30	3.71	3.71	3.30	3.30	3.30	3.30	3.30	3.30
8	3.02	3.30	4.01	3.30	3.71	3.71	3.71	4.11	4.11	4.40	4.40	4.40	3.71	3.71	4.01	4.01	3.30	3.30	3.30	3.30	3.30	3.02	3.02	3.30
9	3.68	3.68	3.71	4.11	4.11	4.11	4.28	4.67	4.01	4.01	4.31	4.31	3.68	3.68	3.68	4.01	3.68	3.68	3.30	3.39	3.39	3.02	3.39	3.02
10	3.68	3.68	3.98	3.68	3.68	4.01	3.71	3.71	4.67	4.17	5.11	5.46	5.11	5.35	5.11	5.14	5.35	5.20	4.75	4.40	4.75	4.40	4.75	4.75
11	4.75	4.31	4.40	5.01	4.33	5.28	4.56	4.56	5.22	5.22	5.22	5.22	4.24	4.96	3.81	3.81	3.46	3.46	3.81	3.81	3.46	3.46	3.46	3.46
12	3.46	3.46	3.30	3.46	3.98	3.30	3.84	3.68	3.47	3.20	3.52	3.52	3.17	3.11	2.74	3.98	3.46	3.71	3.71	3.09	3.09	3.30	3.30	3.30
13	3.02	3.68	3.71	4.01	4.96	4.71	5.22	4.85	4.59	4.85	4.56	4.56	4.56	4.96	4.96	4.67	4.81	5.01	5.01	4.75	4.75	4.31	4.31	4.31
14	3.68	3.68	3.68	3.68	4.31	4.01	4.01	4.01	4.01	4.31	4.31	4.40	4.31	4.31	4.31	4.31	4.31	3.98	4.31	3.68	3.98	4.31	3.98	3.98
15	4.01	4.01	3.71	4.40	4.41	4.75	4.33	4.96	4.56	4.24	4.24	4.24	4.33	3.81	4.11	3.81	3.46	3.30	3.30	3.30	3.30	3.68	3.62	3.62
16	3.68	3.68	4.01	3.81	3.81	4.67	3.52	4.96	4.96	4.96	4.96	4.96	4.96	5.01	4.40	4.40	4.11	4.75	4.46	4.67	5.01	5.01	5.01	5.01
17	5.01	4.67	5.60	5.26	5.28	5.97	6.27	6.27	6.27	6.27	5.83	6.27	6.25	5.60	5.60	5.60	5.35	5.35	5.77	4.40	4.75	4.75	4.75	4.52
18	4.75	4.75	5.35	5.35	5.35	5.32	5.60	6.08	6.43	6.43	6.62	5.84	5.84	5.84	5.77	5.77	5.11	5.11	5.77	5.77	5.77	5.35	5.77	5.77
19	5.77	5.35	5.77	5.77	6.32	5.77	6.32	6.32	6.32	6.32	6.32	5.84	6.72	5.77	4.75	4.75	4.75	4.01	4.01	4.31	3.30	3.30	3.30	4.01
20	4.01	3.30	3.30	3.30	3.30	3.30	3.30	3.71	4.40	4.40	4.40	4.40	3.71	3.30	3.30	3.30	3.30	3.30	3.09	3.30	3.30	3.30	3.30	3.30
21	4.01	4.40	4.40	3.71	3.71	4.40	4.11	4.11	4.11	4.67	5.01	5.01	5.35	4.01	4.01	4.01	5.11	4.75	4.31	4.01	4.01	4.31	5.11	4.31
22	3.30	4.01	3.46	3.71	4.11	4.11	4.33	4.56	4.98	5.22	5.59	5.10	4.24	4.24	4.56	4.24	5.22	5.22	5.22	5.59	5.59	5.28	5.01	4.40
23	5.35	5.01	5.01	5.60	5.28	5.28	5.84	5.35	6.18	6.18	6.18	6.18	6.18	6.39	6.39	6.18	6.18	6.18	5.77	6.18	6.18	6.18	5.11	5.11
24	5.46	5.11	5.11	5.11	5.11	5.11	5.11	5.11	4.75	5.11	4.75	5.77	4.75	5.11	5.11	5.46	5.77	5.77	5.35	4.75	4.75	5.11	5.11	4.75
25	4.31	4.41	4.75	4.75	4.40	4.40	4.40	5.01	5.01	5.01	5.01	5.01	4.75	4.75	4.40	4.40	3.71	3.75	4.05	4.00	4.01	4.01	4.01	4.01
26	4.01	4.40	4.11	4.11	4.61	4.67	4.67	4.67	4.67	4.67	4.33	4.33	4.33	4.33	3.71	4.01	4.31	4.01	3.68	4.01	3.30	3.68	3.68	3.68
27	4.31	4.01	4.40	4.11	4.67	4.67	4.96	4.33	4.33	5.28	4.33	4.96	4.67	3.71	4.01	4.40	4.01	4.01	4.01	4.01	3.68	3.68	3.68	3.68
28	3.30	4.01	3.46	3.81	4.11	4.11	4.67	4.67	4.67	5.28	5.28	4.33	5.01	4.40	4.11	4.40	4.40	4.40	3.71	4.31	4.01	4.01	3.71	4.40
29	4.01	4.01	4.40	4.40	4.40	4.11	4.11	3.81	4.40	4.40	4.11	4.40	4.40	4.01	4.31	4.75	4.75	4.07	4.01	4.01	4.01	4.01	4.31	4.01
30	4.01	3.68	4.31	3.81	4.67	4.33	5.60	5.28	5.97	6.43	5.28	5.28	5.84	5.01	5.35	5.77	4.75	4.75	4.75	5.11	4.75	4.75	4.75	4.75

NOTE.—Data in Exhibits IV. and V. represents grains of moisture per cubic foot of air.

Exhibit V

October	A.M.							P.M.												A.M.				
	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5
1	5.46	6.18	7.08	6.62	6.27	6.27	6.64	6.39	6.39	7.73	7.73	7.65	8.15	7.65	7.16	7.08	6.32	7.08	6.32	6.72	6.72	7.20	6.18	6.18
2	7.20	7.92	8.86	9.38	9.02	10.15	10.15	10.15	16.10	10.15	10.15	9.38	10.02	10.02	8.86	8.86	8.86	7.92	7.92	8.86	8.40	8.40	8.40	7.20
3	7.92	7.92	9.38	9.02	9.57	9.57	9.13	9.78	9.78	9.14	10.89	10.15	8.54	8.54	8.54	8.86	7.92	7.92	7.64	8.86	8.54	9.51	7.92	9.05
4	9.05	7.92	8.54	9.02	10.15	10.15	10.15	9.02	10.02	10.02	10.27	10.02	9.02	9.38	9.38	9.02	8.86	8.86	9.05	9.84	9.51	9.84	8.40	9.84
5	8.40	9.51	9.51	8.40	9.51	9.51	9.51	8.86	8.86	8.54	8.54	9.51	7.64	7.64	7.64	7.92	8.40	6.72	7.92	6.72	5.77	5.77	5.77	5.35
6	5.35	5.35	5.35	5.01	5.60	5.28	4.96	5.59	5.22	5.22	5.59	5.28	5.01	5.35	5.11	5.11	5.11	5.11	5.11	5.46	5.99	5.11	5.77	5.11
7	6.18	6.18	5.77	5.35	6.32	6.32	7.64	7.92	7.20	8.40	7.92	7.92	7.52	7.20	7.20	7.20	7.20	7.20	7.20	7.20	7.52	7.52	7.52	6.18
8	7.20	7.20	7.20	6.72	6.72	5.60	5.28	6.43	6.43	5.81	6.32	6.72	6.72	6.72	5.77	5.77	5.77	5.77	6.18	5.77	6.18	5.11	6.18	5.11
9	5.46	5.46	6.18	5.35	4.67	4.56	4.85	5.22	4.85	5.22	4.56	5.77	4.40	5.11	5.11	5.11	4.31	4.31	4.40	5.11	5.11	4.31	4.66	4.66
10	4.66	5.11	4.75	4.75	5.77	6.62	7.47	7.47	8.15	7.25	6.71	7.47	7.08	7.08	7.08	7.47	7.25	6.71	6.71	6.43	6.43	5.60	5.84	......
11	6.32	6.43	6.71	6.27	5.83	6.39	6.71	5.97	5.35	4.75	4.75	4.75	6.72	5.77	5.77	5.77	5.77	6.18	6.18	4.66	4.31	5.11	5.11	4.31
12	4.31	3.75	4.01	3.81	4.33	3.98	3.71	3.71	3.71	3.98	3.98	3.52	3.52	3.82	3.81	4.01	4.01	4.01	4.31	4.31	4.31	4.31	4.31	4.31
13	4.31	4.31	4.01	5.01	5.28	5.28	4.85	4.85	4.47	4.24	4.24	4.56	4.67	4.67	4.67	4.75	5.35	4.75	5.11	4.75	4.75	4.40	3.81	3.46
14	3.11	3.11	3.46	3.11	3.11	3.11	3.11	2.75	3.46	3.71	3.71	3.71	3.71	3.71	3.71	4.01	4.01	3.71	4.11	4.11	4.11	4.11	3.46	3.46
15	3.81	3.46	3.46	3.11	3.11	3.81	3.81	3.52	3.98	3.52	3.52	3.11	3.81	3.11	4.01	4.01	3.30	3.30	3.68	3.68	3.68	3.68	3.68	3.68
16	3.68	3.68	3.68	4.01	4.11	4.33	4.33	4.33	3.98	3.98	5.01	3.71	4.40	4.01	4.01	4.01	4.01	4.01	4.01	4.01	3.71	3.71	3.71	3.71
17	3.71	3.71	4.40	3.81	3.30	3.84	4.01	4.01	4.01	4.47	4.47	4.47	3.52	3.84	3.84	3.30	4.24	3.30	3.71	4.54	6.67	4.67	4.33	3.81
18	4.40	4.75	4.75	4.75	4.75	4.75	4.75	5.11	4.75	4.75	4.75	4.11	4.11	4.40	4.11	4.40	4.11	4.40	3.71	3.71	3.71	3.71	4.01	3.71
19	3.71	3.68	4.01	4.11	3.98	3.71	3.30	2.95	2.95	3.84	3.84	3.98	3.98	3.81	4.11	3.71	3.46	3.71	4.01	4.01	4.01	3.68	4.01	4.01
20	3.68	3.68	4.01	4.01	4.33	4.56	3.84	4.85	3.82	4.01	4.24	4.24	4.67	4.11	4.11	4.40	4.40	4.40	4.11	4.11	5.01	4.40	4.75	4.75
21	5.77	5.35	5.77	5.77	6.18	5.77	5.77	5.77	5.77	5.35	6.32	5.01	5.35	5.35	5.77	6.72	5.35	5.35	5.77	5.77	4.40	4.40	4.40	3.46
22	3.46	3.46	3.46	3.46	3.46	3.11	3.46	3.46	3.46	3.46	3.46	3.52	3.81	3.81	3.52	3.11	3.11	3.81	3.81	3.81	3.81	3.81	3.81	3.81
23	3.52	3.52	3.17	3.52	2.75	3.52	3.17	3.17	3.52	3.17	3.52	3.11	3.52	3.52	3.11	3.11	3.46	3.46	3.46	3.09	3.71	3.09	3.30	3.30
24	3.30	3.30	3.71	3.46	4.33	3.98	4.96	4.56	4.24	4.24	4.56	4.67	3.81	4.11	4.11	4.11	4.40	3.71	3.71	3.71	3.71	4.01	4.01	3.71
25	4.01	3.30	3.71	4.11	4.33	4.24	4.85	4.85	4.01	4.47	3.84	3.98	4.33	4.11	3.46	3.71	3.71	4.01	4.40	4.40	4.11	4.11	4.11	4.11
26	4.16	3.71	3.46	3.46	2.74	2.75	2.75	2.75	3.11	3.46	3.46	3.09	3.11	3.46	3.11	2.74	2.74	2.74	2.52	2.75	2.23	2.52	2.74	2.52
27	2.52	2.23	2.52	2.23	2.23	2.23	2.23	2.75	2.75	2.45	2.45	2.52	2.74	2.74	2.74	3.09	3.09	3.09	2.47	3.09	3.09	3.09	2.47	3.09
28	3.30	3.30	2.74	3.46	2.75	2.75	2.94	2.94	3.30	3.30	2.94	2.75	2.74	3.11	3.46	2.74	3.09	3.46	2.74	3.09	3.46	3.09	3.09	3.30
29	2.74	2.74	2.74	3.09	2.75	3.52	3.71	2.95	3.30	3.30	2.58	3.81	3.11	3.11	3.46	3.11	3.46	2.75	3.11	3.11	3.09	3.09	3.09	3.09
30	3.30	3.46	3.30	3.46	4.01	3.71	3.46	3.46	3.46	3.11	2.75	3.17	2.75	3.11	3.46	3.46	3.11	3.11	3.11	3.11	3.46	3.46	2.74	3.71
31	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.71	3.46	3.46	3.46	2.75	3.46	3.46	3.09	3.09	3.09	3.09	3.09	3.30	3.39	2.77	3.09	3.30

It is true that the atmosphere has been recognized by many metallurgists as the cause of many and serious irregularites in blast-furnace operations, but it is doubtful if its influence has been adequately recognized. Many writers on metallurgical subjects have considered the moisture in the atmosphere, and calculated the absorption of heat necessary for its dissipation — and invariably underestimated; and have dismissed the subject with the conclusion that to extract the moisture the game was not worth the candle, or in a spirit of resignation accepted it — like storm and sunshine — as a condition beyond our control. This conclusion has no doubt been reached by a consideration alone of the quantity of fuel necessary to dissipate the moisture in the furnace hearth, based on observations of the humidity of the atmosphere taken outside the blowing-engine room, and this quantity, while important, does not indicate a great saving in fuel. Of much greater importance is the variation in moisture from time to time, and the margin of heat carried in the furnace to compensate for these variations, which margin is invariably large; and every furnace manager is aware of its existence, from the way in which he is required to manipulate the hot-blast temperatures, and from the silicon in the metal, which is the thermometer of the hearth.

It has often been a matter of surprise that a greater saving of fuel per ton of iron was not obtained in the winter, as compared with the summer season, as the records show a much less content of moisture in the atmosphere, the reason being that blowing engines at blast-furnaces do not receive air of the dryness as shown in the exhibits above. In summer the windows and doors of the blowing-engine room are wide open, and the supply of air, with reference to humidity, is practically that of the atmosphere; but in winter they are nearly or quite closed, and the entering air has mixed with it all of the steam that leaks from the engine and is contaminated therewith. Records taken over a number of years show that there is not a very great difference in the moisture in atmosphere between observations taken outdoors in summer and in the engine room in winter. In Exhibit VI are monthly records showing a comparision between winter and summer months, the observations having been taken indoors and outdoors respectively.

Exhibit VI

Winter Month.	Grains of Water per Cu. Ft. of Air	Summer Month.	Grains of Water per Cu. Ft. of Air
January	4.5	April	4.2
February	4.6	May	4.1
March	4.7	June	6.4
October	6.4	July	5.2
November	4.6	August	6.7
December	5.0	September	5.7

A comparison of the data given in Exhibit VI with Exhibit II would suggest that a great advantage could be derived by leading pipes from outdoors to the inlet-valves of the air cylinder, and it certainly appears that a material advantage could be gained. So impressed was the writer with this conclusion that the blowing engines at a furnace under his direction were so equipped in the month of January, and continued to draw the supply of air from outdoors throughout the year. The excellent results expected in the winter season did not materialize, or rather were so slight, as compared with a companion furnace not so equipped, as to argue against any extension along that line. This experience suggested the conclusion that while the air in the engine room was higher in its content of moisture, through its admixture with steam, than the outside air, yet it was not subject to the same variations; and further that these variations, which were often sudden and great, were really the most troublesome feature, and that nothing less than maintaining the atmosphere uniform with respect to humidity would prove of any material advantage. The saving in fuel through such uniformity could not be accurately set forth. The amount of fuel necessary for the decomposition of the moisture in the blast can be closely arrived at, but to what extent that which might be designated as the surplus of heat, utilized for counteracting the variations in moisture, could be diminished, must of necessity be an approximation, as there existed no tangible data for estimating it. Nevertheless, the saving therein was deemed to be considerable.

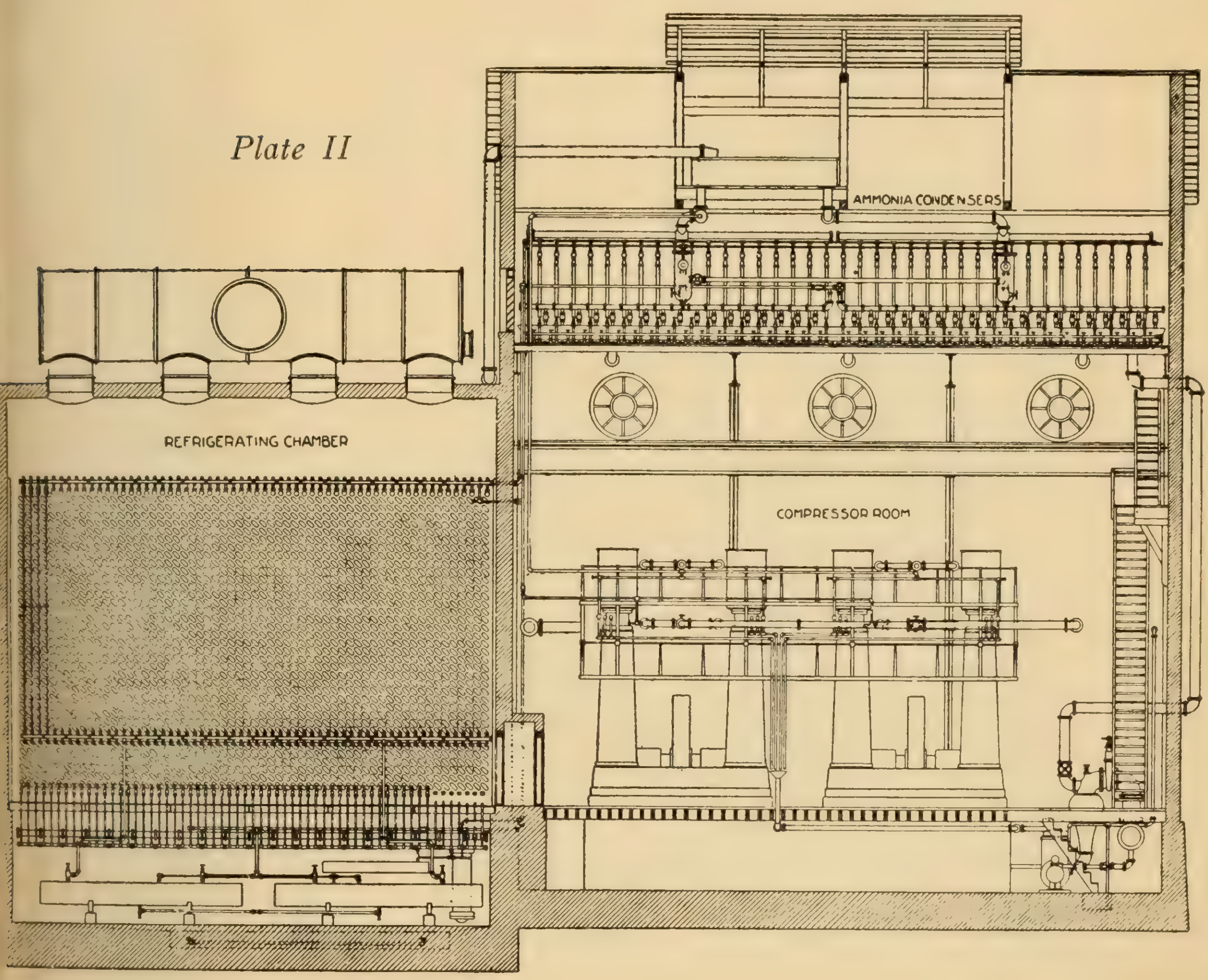
It may reasonably be assumed that in order to determine the most feasible method and apparatus for extracting the moisture, a wide field of experiment must be covered. Various schemes for absorbing the moisture were worked out and in turn

Plate I

abandoned, and refrigeration by means of anhydrous ammonia was chosen. After many preliminary experiments an insulated chamber containing coils of pipe, and of sufficient size to treat the air from a blowing cylinder three feet in diameter, was built. A small ice machine was installed to circulate the ammonia

through the coils, and the air was admitted to the refrigerating chamber from an auxiliary chamber in which steam could be introduced at will, thus making it possible to treat, at any time, air containing the maximum amount of moisture with which it would be necessary to contend in the summer months. In this experimental plant air was treated under a variety of con-

Plate II



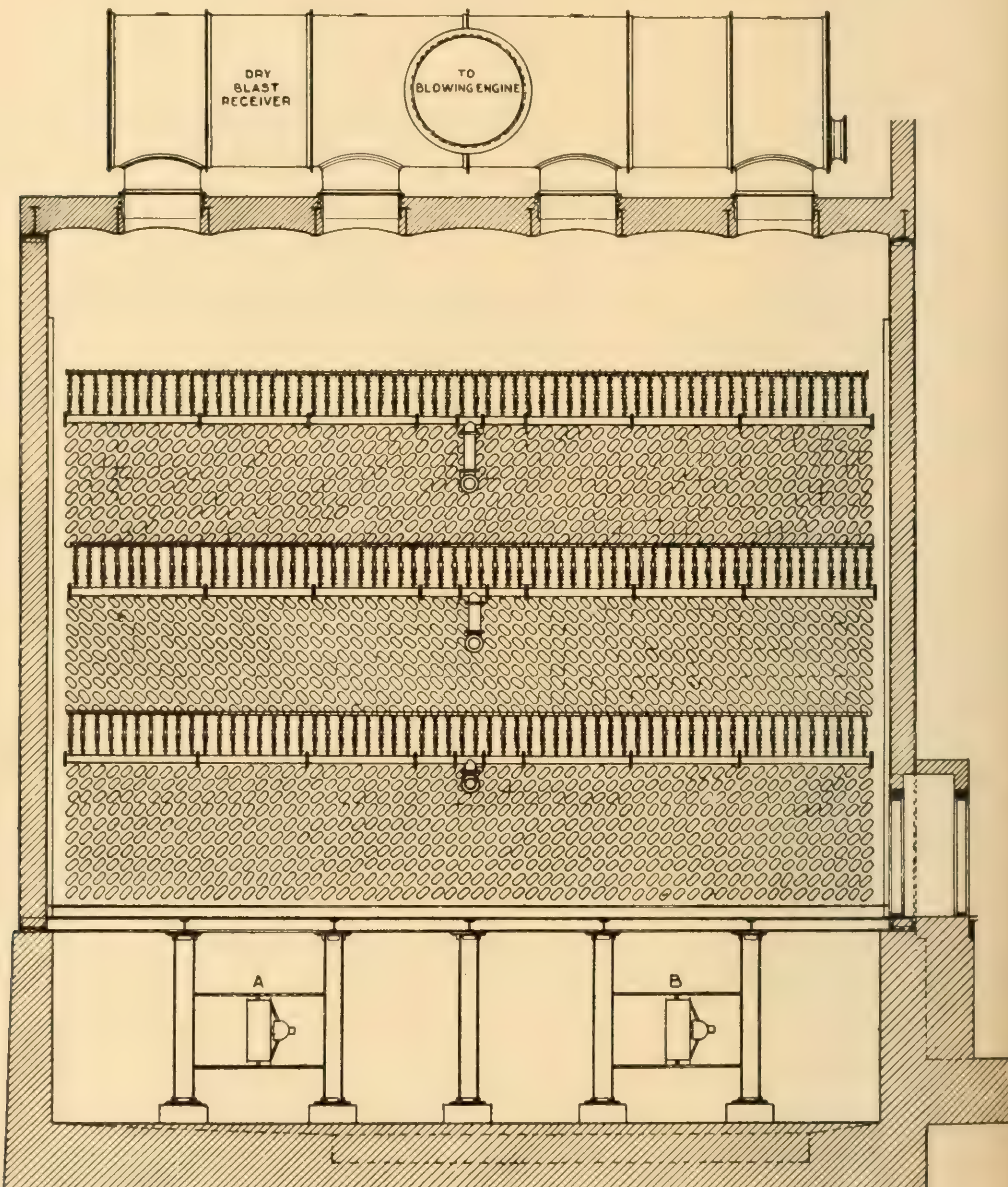
ditions for quite a period, and from the data obtained the equipment for a modern furnace was worked out.

The Isabella Furnaces of the Carnegie Steel Co., located at Etna, Pa., a suburb of Pittsburg, were selected as the plant at which to install the apparatus for applying the dry-air blast.

The lines and dimensions of this furnace are shown in Plate I, and represent the usual construction of furnaces in the Pittsburg district. The furnace is blown with twelve six-inch tuyères,

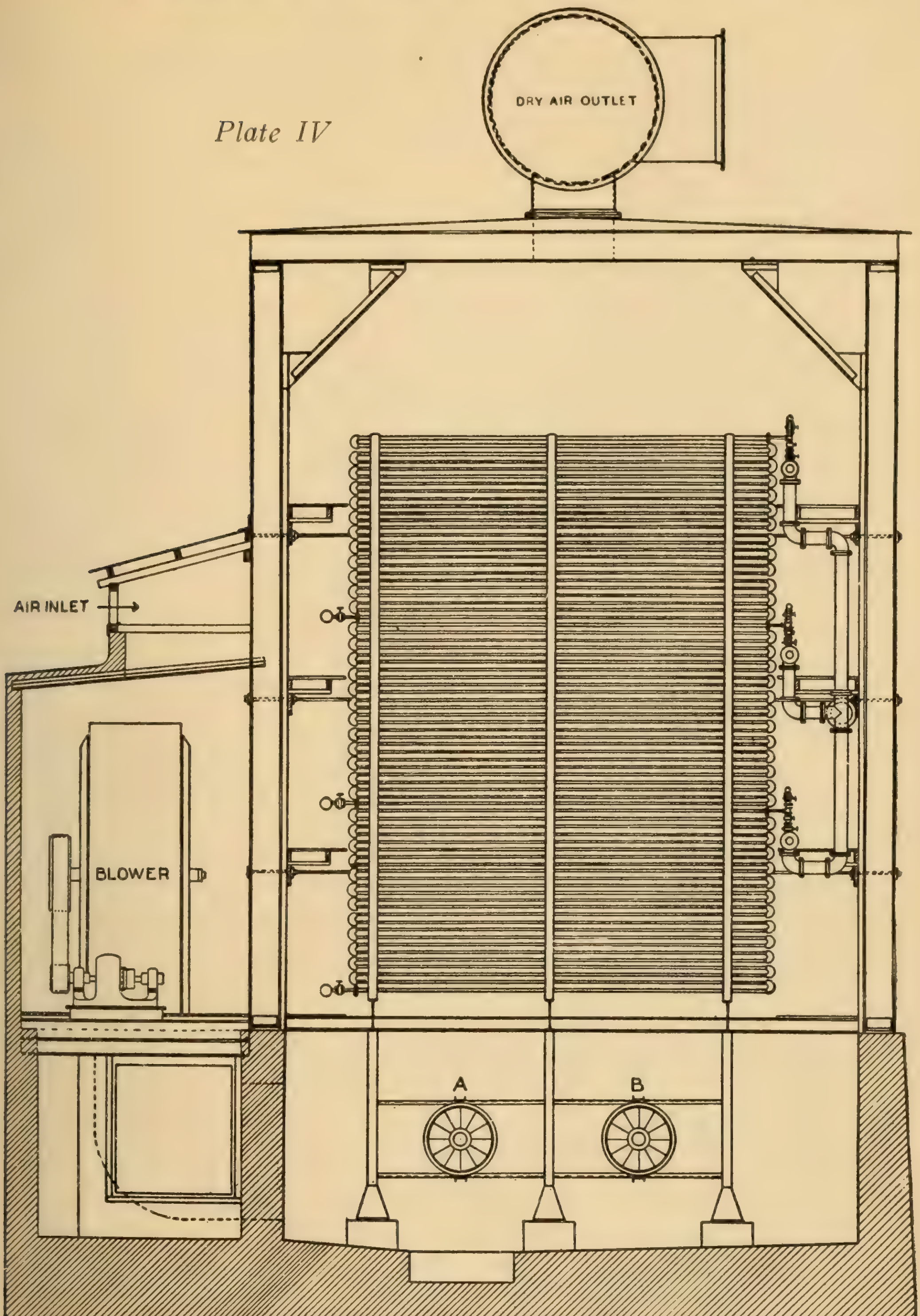
and is equipped with four hot-blast stoves. Blast is supplied by three blowing engines having the following dimensions: steam cylinder, 44 inches diameter; air cylinder, 84 inches; stroke, 60 inches.

Plate III



In Plate II there are shown in elevation the ammonia compressors, condensers, and the refrigerating chamber. This view of the refrigerating chamber shows it to be connected for the direct expansion of ammonia, but as the escape of ammonia

Plate IV

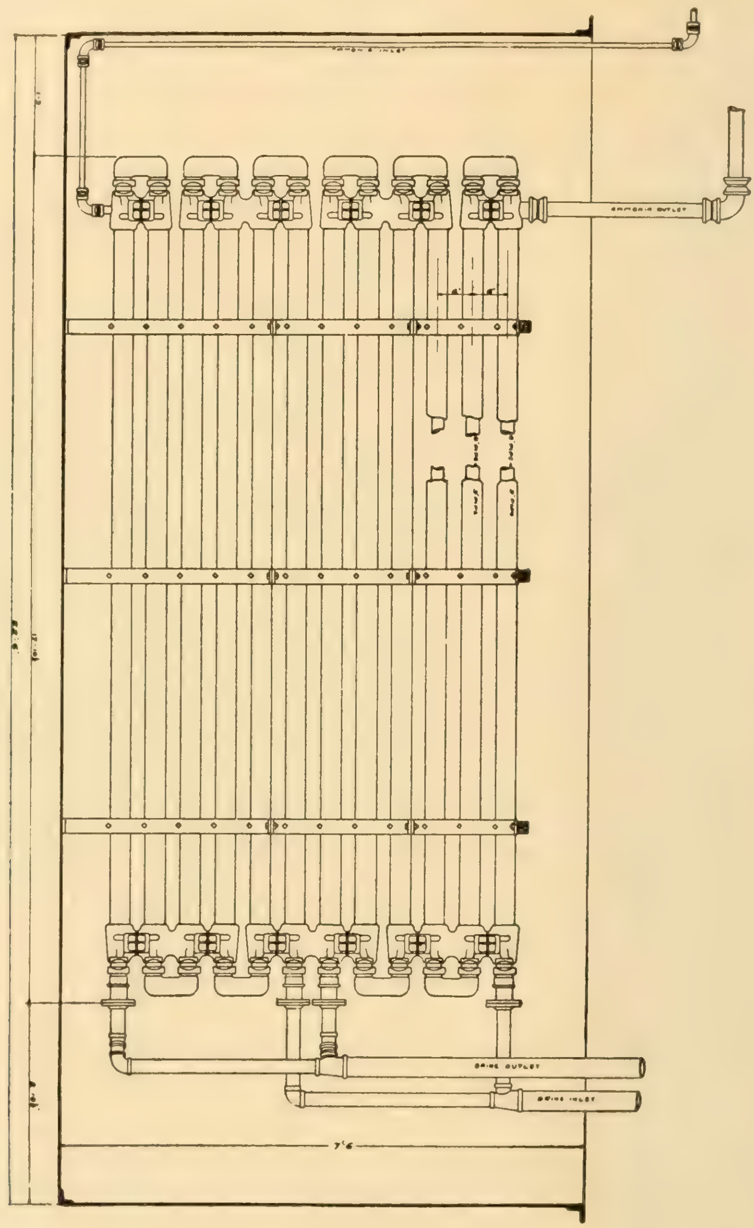


gas through a broken pipe or leaking joint might imperil the life of anyone in the chamber at the time, it was decided to adopt the brine system, and the pipe connections are as shown in Plates III and IV, representing the refrigerating chamber

in end view and vertical section. The refrigerating chamber is lined on the inside with plates of compressed cork two inches thick.

The ammonia machines are of the compressor type, and

Plate V



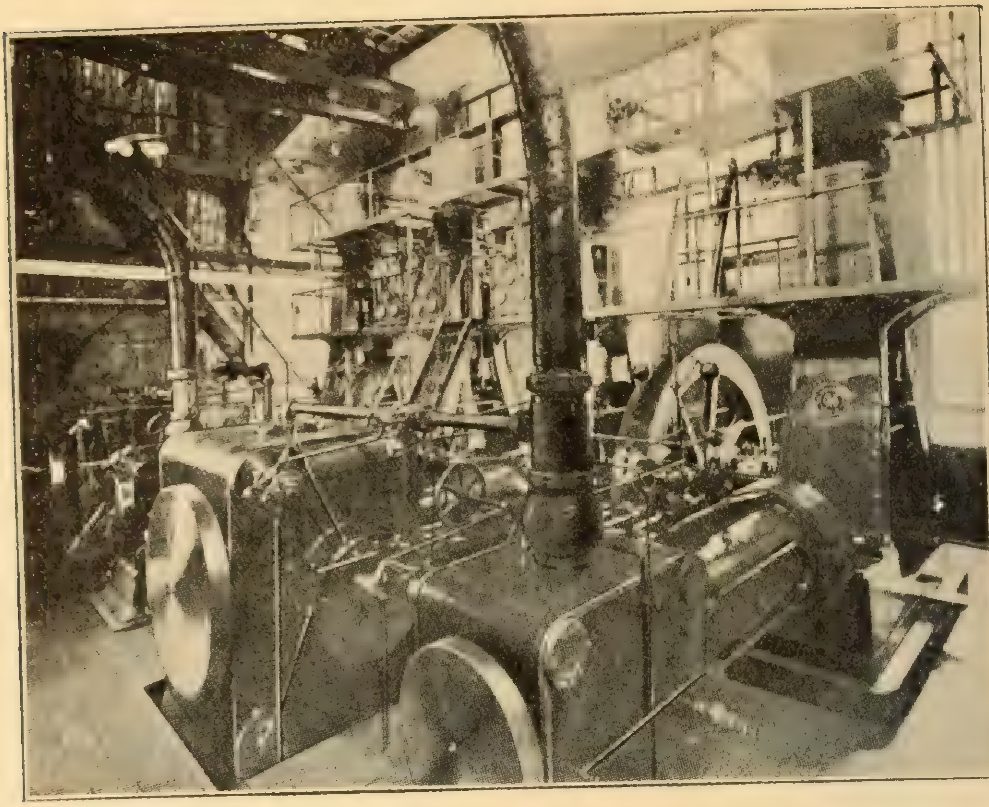
were built by the York Manufacturing Co., York, Pa. The dimensions are as follows: diameter high-pressure steam cylinder, 28½ inches; low-pressure, 56 inches; compressor cylinder, 22½ inches; stroke, 36 inches. Two compressors were

installed in order to have one in reserve at all times, as a furnace operating on uniformly dry air cannot be subjected to ordinary atmospheric conditions without serious results, and frequently on very humid days the assistance of the second engine might be required. Each compressor has a capacity of 225 tons ice melting effect.

Plate V shows the brine-tank, in which are twenty coils of pipe of the dimensions shown in the diagram. The coils are covered with calcium chloride brine having a specific gravity of 1.21. The return brine from the refrigerating chamber flows into the top of the tank, is cooled by the ammonia expanding between the outer and inner pipes, withdrawn therefrom by a pump and forced back through the pipe marked "brine inlet" into the two-inch or inner pipes, where it is cooled below the freezing point, and thence into the coils in the refrigerating chamber. The ammonia enters at the bottom of the pipes, thus traveling in the opposite direction from the brine, and by expanding between the two-inch and three-inch pipe cools the brine both in the tank and in the inner pipes. Forty thousand gallons of brine are required in the system.

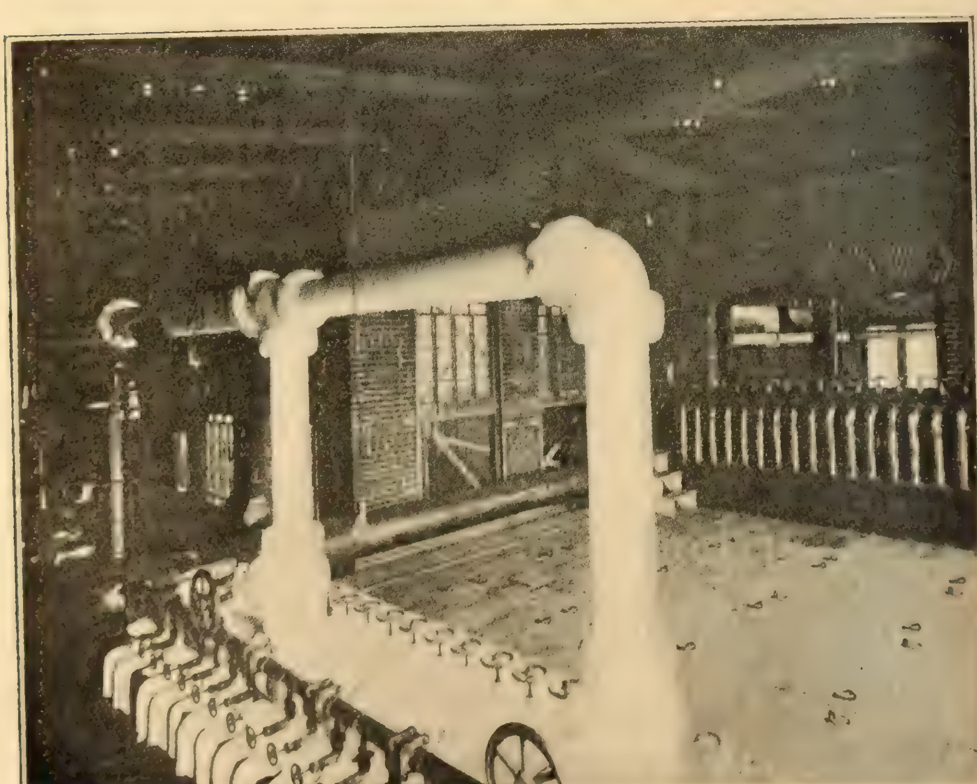
In Plates III and IV is shown the arrangement of pipes in the refrigerating chamber. There are in each vertical line of coils seventy-five two-inch pipes 20 feet long, and in the chamber there are sixty vertical lines of coil, the whole representing 90,000 lineal feet of two-inch pipe in the chamber. The pipes in each vertical coil are placed in staggered position to insure better contact with the air. The series of coils is divided into three sections and fed through a four-inch header, and discharges into a six-inch header, thence into a standpipe, from which the brine flows to the brine tank, its feed being arranged to cause the brine to flow in a direction opposite to that of the air. As the space between the pipes would become gradually reduced through the accumulation of frost, which might diminish the efficiency of the blowing engine, a blower was installed to force air into the refrigerating chamber, and in order to secure a uniform distribution of air over the coils revolving electric fans (marked 1 and 2) were placed in the space underneath, so that all of the coils would frost alike. The entering air, according to its humidity, deposits the moisture in the form of water or frost on the lower pipes and as frost only on the

Plate VI



Ammonia Compressors.

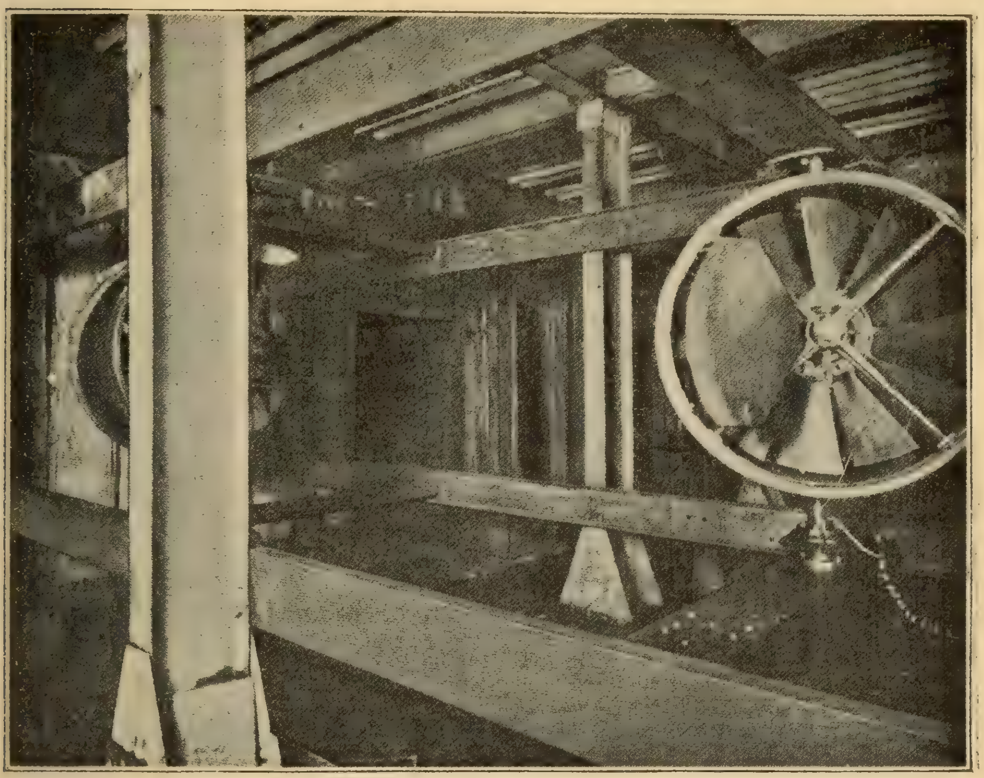
Plate VII



Brine Cooling Tank.

upper pipes, and passes from the top of the chamber to the blowing engines at a temperature of freezing or below and with a practically uniform content of moisture. When the pipes become covered with frost the cold brine is shut off from several vertical lines of coil at a time, and through an auxiliary pump and line of pipe, brine that has been heated in a tank with steam is forced through, and in a few minutes the frost is melted. Connection is then made with the cold-brine system,

Plate VIII



Circulating Fans Under Refrigerating Coils.

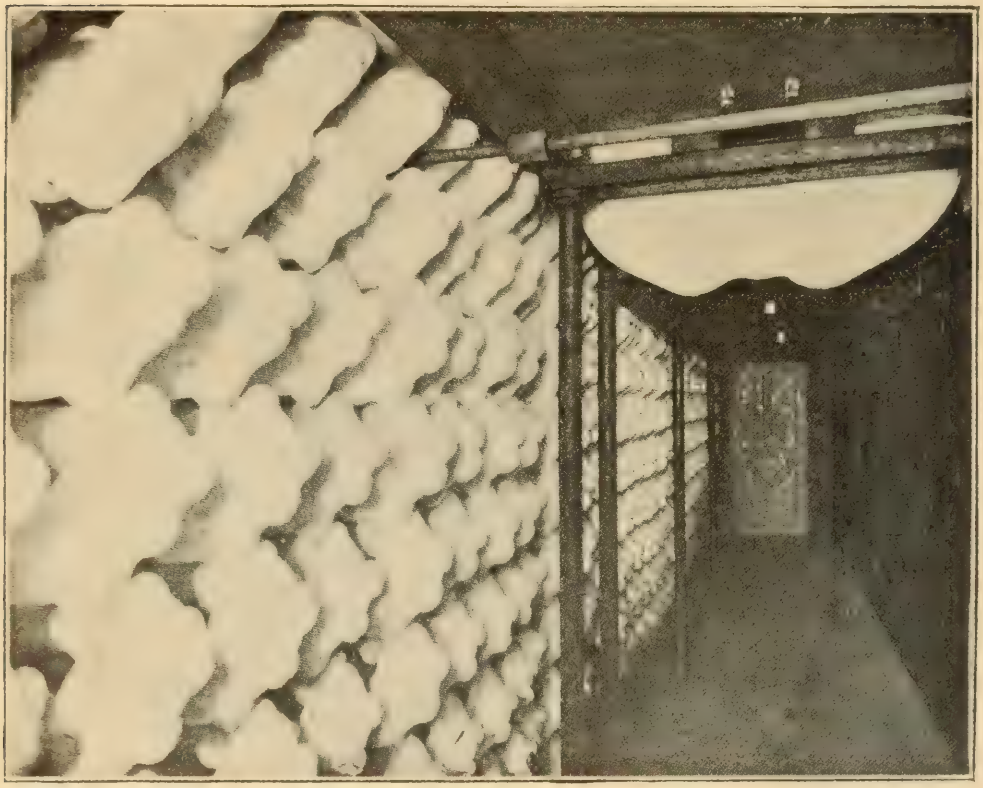
and frost begins to deposit quickly. The frost which has been melted off the pipes collects in a trough in the basement floor, from which it flows into the supply tank for the condenser.

The dry-blast plant is constructed throughout in the most substantial manner, for it is obvious that an apparatus treating such an important element of the process as the atmosphere could not be practically applied to a modern furnace in an experimental way, but must of necessity be as ample in capacity

and as substantial in construction as any of the present day accessories of the furnace stack.

The dry-blast plant was put in operation on August 11, 1904. The furnace was making a grade of iron suitable for the basic open hearth furnace, containing less than one per cent silicon, with an ore mixture consisting of 50 per cent Mesabi ore, the balance being soft hematites from Michigan. The mixture showed a yield by analysis of 53.5 per cent iron. The coke

Plate IX



Refrigerating Chamber, Showing Frosted Ends of Coils.

used was shipped from two mines and contained on an average 10.5 per cent and 12.5 per cent of ash respectively, and also varied considerably in ash. In order to obtain correct data from the use of the dry blast, it was determined beforehand that no changes in any particular were to be made in the operation of the furnace, other than the introduction of dry air, and this has been rigidly adhered to. In the data following a comparison is made between the operations of the furnace using

dry air after August 11th and those from August 1st to 11th, when the furnace was using the atmosphere under ordinary conditions. A comparison with the previous month would show a greater economy in coke, but since a change was made in the ore mixture in the latter part of July — which gave a lower coke consumption per ton of iron — a comparison of data when using dry air with that obtained in August prior to its use, and with the same ore mixture, would more accurately show the benefits derived. The burden on the furnace from August 1st to 11th inclusive was as follows:

Coke	10,200 pounds
Ore	20,000 pounds
Stone	5,000 pounds

On August 11th five per cent increase in burden was put on the furnace and later in the day 33 per cent of dry blast was used. As soon as this small quantity was introduced its effect was noticeable by a brightening of the tuyères and an increasing temperature of the cinder. After this change in burden had come to work and the condition of the furnace showing, if anything, more satisfactory, an additional five per cent of

Exhibit VII

Without Dry Blast	Product Tons	Coke Consumption Pounds	With Dry Blast	Product Tons	Coke Consumption Pounds
Aug. 1	360	2,210	Aug. 25	462	1,766
Aug. 2	367	2,112	Aug. 26	441	1,850
Aug. 3	372	2,084	Aug. 27	477	1,668
Aug. 4	373	2,133	Aug. 28	516	1,462
Aug. 5	386	2,008	Aug. 29	405	1,763
Aug. 6	340	2,280	Aug. 30	441	1,804
Aug. 7	347	2,116	Aug. 31	462	1,722
Aug. 8	360	2,012	Sept. 1	472	1,729
Aug. 9	378	2,114	Sept. 2	472	1,642
Aug. 10	352	2,318	Sept. 3	458	1,648
Aug. 11	306	2,266	Sept. 4	421	1,841
			Sept. 5	450	1,813
Average	358	2,147	Sept. 6	400	1,683
			Sept. 7	400	1,734
			Sept. 8	397	1,952
			Sept. 9	472	1,642
			Average	447	1,726

burden was put on with confidence, feeling assured that an increased use of dry-blast would offset the increased duty on the furnace. From this period on the burden and volume of dry blast were increased more slowly until, on August 25th, the furnace, using dry blast entirely, had the following burden at work:

Coke	10,200 pounds
Ore	24,000 pounds
Stone	6,000 pounds

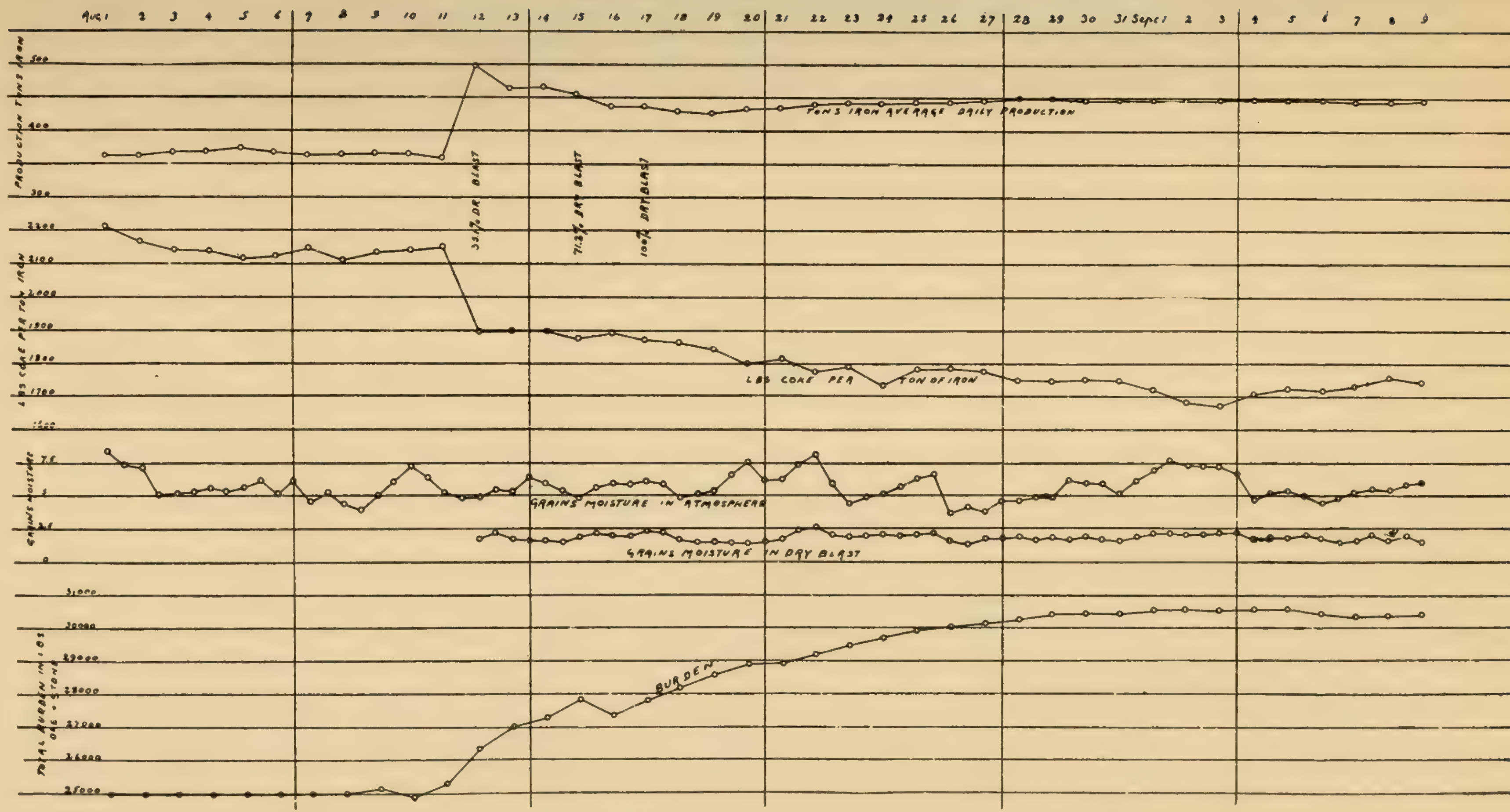
thus in two weeks obtaining an increase in burden of 20 per cent. The record of the furnace from August 1st to 11th, prior to the use of the dry blast, and from August 25th to September 9th inclusive, using all dry-blast, is shown in Exhibit VII.

In Plate X there is graphically set forth the record of furnace operations from August 1st to September 9th inclusive. This shows the increase in output and reduction in coke consumption corresponding to the increase in burden. There is also shown the varying conditions of humidity from day to day, which represent the average humidity for each twelve-hour period, and the change in humidity after being treated in the dry-blast apparatus. While the reduction in moisture and its increase in uniformity is considerable, it should not be lost sight of that this represents the beginning of operations, and there was still much to be learned with respect to manipulation of the dry-blast plant.

The effect of reducing and making more uniform the moisture in the blast was clearly shown when, during a period of excessive humidity extending over three days, a neighboring furnace charged during this period an extra quantity of coke and increased the quantity each day in order to maintain the grade of iron, while the Isabella furnace, operating on dry blast, was in no wise affected.

On September 10th it was found necessary to make some repairs to the compressors and to make connections to a new brine-header for thawing off the coils, and the burden was lightened accordingly. After these repairs had been made the burden was again increased, and from September 17th to 30th inclusive the furnace showed an average daily output of 452

Plate X



PRODUCTION TONS IRON
LBS COKE PER TON IRON
GRAINS MOISTURE
TOTAL BURDEN IN LBS ORE + STONE
TONS IRON AVERAGE DAILY PRODUCTION
33.1% DR BLAST
71.3% DRY BLAST
100% DRY BLAST
LBS COKE PER TON OF IRON
GRAINS MOISTURE IN ATMOSPHERE
GRAINS MOISTURE IN DRY BLAST
BURDEN

tons, with a coke consumption of 1,729 pounds per ton of iron.

In order to show what changes have been made in the atmosphere by passing it through a refrigerating chamber, the following daily records of operations, as set forth in Exhibit VIII, will give a very clear idea.

Exhibit VIII

Time.	Temperature.		Grains of Water per Cu. Ft. Air.		Temperature.		Grains of Water per Cu. Ft. Air.		Temperature.		Grains of Water per Cu. Ft. Air.	
	Inlet.	Outlet.	Inlet.	Outlet.	Inlet.	Outlet.	Inlet.	Outlet.	Inlet.	Outlet.	Inlet.	Outlet.
6 A.M.	68	21	5.19	1.33	70	22	6.35	1.70	77	22	3.94	1.48
7 A.M.	68	20	5.02	1.24	71	22	6.78	1.77	......	......	4.08	1.29
8 A.M.	70	20	5.56	1.55	69	22	6.67	1.62	......	......	4.22	1.42
9 A.M.	73	20	5.37	1.46	73	22	6.78	1.70	71	25	4.85	1.36
10 A.M.	74	20	5.47	1.81	74	22	6.78	1.70	......	......	5.02	1.48
11 A.M.	77	20	5.56	1.53	77	23	6.67	1.70	......	......	5.19	1.55
12 M.	77	21	6.01	1.53	81	23	6.56	1.62	81	28	5.37	1.70
1 P.M.	80	21	6.04	1.42	78	24	6.56	1.70	......	......	4.85	1.62
2 P.M.	81	22	6.14	1.60	82	25	6.56	1.90	......	......	4.85	1.62
3 P.M.	81	23	5.74	1.60	81	24	6.19	1.74	84	29	5.02	1.70
4 P.M.	82	23	5.74	1.55	81	24	6.19	1.42	......	......	4.68	1.48
5 P.M.	82	22	6.04	1.62	80	24	6.14	1.48	......	......	4.85	1.60
6 P.M.	81	23	5.94	1.55	75	24	5.56	1.55	78	29	5.37	1.77
7 P.M.	80	23	5.74	1.62	72	24	5.94	1.70	.....	......	5.37	1.62
8 P.M.	79	24	5.94	1.55	70	23	5.19	1.62	...	......	5.56	1.70
9 P.M.	73	23	7.01	1.85	69	22	5.19	1.42	72	29	5.74	1.70
10 P.M.	73	22	6.78	1.70	68	21	5.19	1.55	......	......	5.74	1.77
11 P.M.	73	23	6.78	1.70	66	20	3.94	1.77	......	......	5.74	1.62
12 NGT.	73	23	7.01	1.70	62	20	3.54	1.62	66	28	5.56	1.70
1 A.M.	73	23	6.78	1.70	59	18	3.41	1.42	......	......	4.85	1.70
2 A.M.	74	23	7.01	1.70	57	17	3.54	1.13	......	......	5.37	1.70
3 A.M.	73	23	6.78	1.70	56	16	3.18	1.13	64	27	5.19	1.48
4 A.M.	73	23	6.78	1.48	56	16	3.18	0.99	......	......	5.19	1.36
5 A.M.	73	23	6.78	1.48	53	14	2.85	1.06	......	......	4.85	1.48

During a period of thirteen days the average moisture in the atmosphere was 5.66 grains per cubic foot and in the dry air 1.75 grains. Sixty-nine pounds of water were removed from the blast per ton of iron produced, which represents an average of 23,192 pounds (equivalent to 2,784 gallons) for the twenty-four hours. This weight was calculated from the volume of air blown into the furnace, as shown by piston displacement. For four days

during the above period the water caught in the tank underneath the refrigerating chamber amounted to an average of 21,561 pounds (equivalent to 2,588 gallons) for the twenty-four hours, which is as close an agreement as could be expected, considering that the figures do not represent the same number of days, and the difficulty in accurately determining the volume and humidity of the air supplied in a given period. It is found sufficient in practice to thaw the frost off the pipes every three days. The coils are divided, for the purpose of thawing off, into three sections, each representing the same number of coils, and a section is thawed each day, and in this way the work of refrigeration is not interfered with.

As the dry blast was supplied to the furnace it became necessary to reduce the revolutions of the blowing engines, since the air supplied to the engines was lower in temperature than with the natural atmosphere and contained more oxygen per cubic foot, and the tendency of the furnace was to drive too fast. Before applying the dry blast the engines were running at 114 revolutions and supplying 40,000 cubic feet of air per minute; the revolutions were graduallly reduced to 96, thereby reducing the volume of blast over 6,000 cubic feet per minute and increasing the efficiency of the engines by 14 per cent. With dried blast, 96 revolutions per minute of the blowing engines burned nearly one per cent more coke and produced 89 tons more pig iron in twenty-four hours than 114 revoultions on natural air. The reduction in the revolutions resulted in a gain of 150° in temperature of the blast, which even with this increase, through lack of area in the waste gas ports of the stove, did not average above 870°.

The average analysis of the gas for ten days prior to the introduction of the dry blast showed CO, 22.3 per cent; CO, 2.13 per cent with an average temperature of 376°. This reduction in temperature of 162° is a necessary consequence of the greater concentration of heat in the hearth by the dry blast combustion and the greater weight of burden heated by the gas, and represents an important saving of heat in the furnace.

The use of the dry blast has resulted in economies in several other directions. With the use of Mesabi ore, which is very fine in structure, the waste of ore dust through the escaping gases is quite large, and at many furnaces the waste in ore has

become quite burdensome. The waste at the Isabella furnace before dry blast was used amounted to five per cent of the ore charged; this has been reduced, through the greater uniformity in the furnace working, to less than one per cent.

The saving in coke consumption reduces the phosphorus in the metal, and this, in making Bessemer iron, permits the use of higher phosphorus ores. As the Isabella furnace was making basic iron, it was of advantage to keep the silicon as low as possible, provided the sulphur was kept low, and the absence of irregularities in the furnace operations resulting from the dry blast permitted the keeping of the silicon at a lower range without increasing the sulphur. It has been generally observed by furnace managers that when the silicon is lowered through increased humidity in the atmosphere, a leaking tuyère, or through other causes, the sulphur is rapidly increased; but it has been found in using the dry blast, that when the hearth temperature was suddenly lowered, principally from accretions on the bosh reaching the hearth, the sulphur did not increase, and in this respect the furnace has shown a remarkable uniformity in composition of the metal produced.

Mention has been made of the saving effected in the blowing engines through a reduction in the number of the revolutions, and this saving has an important bearing on the expenditure for power in operating the machines in the dry-blast plant. Prior to the use of the dry-blast plant, the blowing engines were indicated and the average horse-power developed by each engine was 900 indicated horse-power. From the cards taken when the furnace was supplied with dry blast, the average indicated horse-power was 671, a difference of 229 horse-power per engine, which aggregates 687 indicated horse power for the three engines. Cards were also taken from the ammonia compressors, the compression and back pressure being kept as nearly as possible to the best working condition. When running at 45 revolutions, which would probably represent the average for the year, each engine developed 230 indicated horse-power, or 460 horse-power for the two engines; the fans together with the brine and water pumps are well covered by allowing for them 75 horse-power, making a total of 535 horse-power. Comparing this with the power saved in the blowing-engine room, there appears an excess above that required for operating the dry-blast plant. These

figures, however, may not represent accurately the difference in power consumption, as the blowing engines were indicated at different times and the first test was taken with a blast pressure on the furnace of 17 pounds, while the test made with the dry blast was 15 pounds, and the figures given above might require some modification, as the effect of dry blast on blast pressure is not yet fully determined. The increase of uniformity in the working of the furnace, which is obtained through the dry blast, would result in a decrease in the blast pressure, and it would appear in any event that the saving in power consumption in the blowing-engine room would nearly or quite compensate for the requirements at the dry-blast plant.

The application of the dry blast to the blast-furnace has shown, in addition to the economies effected, that the furnace can be operated with precision; it works with greater regularity, and in consequence the product is uniform with respect to grade and composition, which makes the dry blast of particular value in the making of foundry iron, which is marketed by grade. An increase or decrease in blast temperature has a definite effect and can be relied on to accomplish the desired result.

The dry-blast plant since it was started on August 11th has been in regular operation. It started without a hitch and no difficulties have developed in any direction. Some modification in construction has been indicated as the result of the operation of the plant which would further reduce the moisture and add to its uniformity, but so far the changes suggested have been slight.

While the application of the dry blast to the blast-furnace has effected various economies and produced a more uniform metal, its further application to the Bessemer converter would no doubt result in great benefit, since air is used in large quantities, and the varying humidity affects the temperature of the charge and in consequence the quality of the steel. The metal from the metal-mixer is remarkably uniform, and the additional uniformity secured through the use of dry air would be of further advantage. It happens that a higher silicon is required in the summer months to maintain the temperature of the blow, in which period it is also more expensive to maintain the right amount of silicon in the pig iron. With the use of the dry blast in the converter the proper temperature could be secured with a

lower silicon in the metal, and this in turn would further reduce the coke consumption at the furnaces. In other processes where air is used in large quantities — particularly in smelters and copper converters and in the open-hearth furnace and in cupolas — it would appear that the use of dry air would effect important economies.

ACID OPEN-HEARTH MANIPULATION *

By ANDREW McWILLIAM and WILLIAM H. HATFIELD

AT the 1902 May meeting of the Iron and Steel Institute the authors presented a paper on "The Elimination of Silicon in the Acid Open Hearth," wherein they recorded a few typical examples of certain Siemens charges out of a very large number specially watched for the purposes of that research. The main deductions drawn from those experiments have been accepted in all the intelligent criticism during or after the discussion on the paper. One opinion, however, was rigidly held by all who mentioned the matter, with the single exception, perhaps, of Mr. Lange, and that was the necessity for the attainment and the maintenance of an abnormally high temperature in order that the percentage of silicon in the metallic bath might increase, or that an unusually large proportion of silicon might be retained in the metal. The original decision was arrived at on the results of scores of trials, and has since been the subject of frequent experiment. The authors still retain their opinion that although, naturally, a higher temperature will accelerate the (probable) action between the carbon of the steel and the excess silica of the slag, they then fairly proved, and have now abundantly confirmed the fact, that around the temperatures occurring in Siemens steel-making practice the chemical composition of the slag, particularly with regard to its acidity, is the factor which determines whether the percentage of silicon in the molten steel shall increase or decrease.

In the discussion in 1902 Mr. Saniter called attention to Mr. H. H. Campbell's work, and in the reply the authors also men-

* The Iron and Steel Institute, New York meeting, October, 1904.

tioned that of Messrs. Winder and Brunton of 1892, the two latter recording the fact of a rise in silicon, and p. 277, sec. x., *g.*, in the former's excellent work on steel making, reads: "*Conditions Modifying the Character of the Product.* — If the temperature of the metal is very high, the last traces of silicon will not be oxidized, for the affinity of silicon for oxygen is a function of the temperature. . . . Thus the open hearth cannot rival the converter in producing high silicon metal by non-combustion, but under suitable conditions the amount carried along in the metal may be quite appreciable, and by holding the bath at a very high temperature with a silicious slag, there will even be a reduction of the silica of the hearth according to the equation $SiO_2 + 2C = Si + 2CO$."

Several heats bearing on this point have been observed, as, for example, one the details of which have been sent recently to the authors, where the carbon of the bath was two per cent at the start, and by adjustment of the slag the silicon was still at 0.4 per cent when the carbon had fallen to 1.4 per cent.

Despite Mr. Saniter's dictum in the 1902 discussion, although large additions to the bath undoubtedly reduce its temperature, it is not necessarily overheated because no additions are being made to the slag. Consider for a moment the case of turning off the gas and air. By these means it is quite easy to keep the temperature normal without the charging of cold material into the furnace.

The authors then tried the experiment of allowing the metal and slag to interact with only small additions of ore, the temperature ranging from normal to slightly hot, and samples ran as follows: 9.00 A. M., carbon, 1.55 per cent; 9.25 A. M., carbon, 1.35; 9.50 A. M., carbon, 1.20, with manganese 0.09 per cent, and silicon 0.60 per cent.

Still further to test the point in as Faraday-like a manner as possible, it was decided to look around for the most silicious material lying about, that might reasonably be expected easily to enter the slag, and the choice fell on a heap of old red bricks of the following average chemical composition:

	Per Cent		Per Cent
Silica	78.9	Magnesia	1.1
Lime	0.4	Alumina	13.3
Ferric oxide	4.7		

TABLE I.—*Red Brick Charge.*

Time.		Composition of Bath.			Additions.		Consistency of Slag.	Composition of Slag.						
Hr.	Min.	C.C.	Si.	Mn.	Materials.	Cwts.		SiO_2.	FeO.	Fe_2O_3.	Al_2O_3.	MnO.	CaO.	MgO.
5	10	...	...	...	Ore	¾	...	...	...	...	...	...	...	...
5	20	...	...	...	,,	1	...	...	...	...	...	...	...	...
5	35	...	...	...	,,	1	...	...	...	...	...	...	...	..
5	40	·45	·037	...	...		fairly thin	51·49	24·90	1·74	2·08	17·57	1·10	0·73
5	45	...	...	...	Ore	1	...	...	...	...	...	...	...	...
5	55	...	...	...	,,	1	...	...	...	...	...	...	...	...
6	0	·31	·034	·039	...		moderately thin	...	...	...	...	...	...	...
6	2-5	...	...	...	Red Brick	8	...	...	...	...	...	...	...	...
6	15	·22	·034	·037	...	...	thickening	...	...	...	...	...	...	...
6	25	·20	·049	·039	...	...	thickening	...	...	...	...	...	...	...
6	35	·17	·049	·039	...	...	thick	55·64	21·38	1·27	4·10	15·19	1·38	0·60
6	40	...	...	...	Ore Lime	½ 1	...	...	...	...	...	...	...	...
6	50	·14	·053	·039	...	...	thinning	...	...	...	...	..	...	...
7	0	·13	·046	·04	...	...	thinner	53·98	21·74	0·86	4·43	14·92	2·10	2·08

Eight cwts. of these were thrown into the furnace in three minutes, and after this (to a Siemens charge) "iced drink" the silicon steadily though slowly rose in accordance with the subsequently ascertained composition of the slag.

Every one must admit that this addition would cool the bath, and as a matter of fact it became comparatively cold. The details of the experiment are given in Table I, and it will be noticed that before the special addition the silicon was fairly low and slowly falling, while after this addition, which raised the percentage of silica in the slag and cooled the bath, the silicon per cent gradually increased.

Owing to an apparently abnormal behavior of the slag in certain trials where a considerable quantity of lime had been added, a special charge was run with the object of watching more closely the effect of lime in the slag on the silicon content of the bath. The slag in one heat was allowed to thicken from 5.50 P. M. to 6.40 P. M., when at 6.41 P. M. 3½ cwts. of limestone were added. This addition had the effect of thinning (increasing the fluidity of) the slag and making it appear more basic than it really was, comparing its fluidity with that of similar slags without lime. Also, with lime present the balance point seems to be slightly altered, perhaps owing to the lime not being an oxidizing base, and with 53.5 per cent silica in the slag, the silicon is not lowered but is slowly increasing. This with other results from the experiment, bearing out the general trend of trials made with other ends in view, and hence not followed out in detail at the time, was useful in the making of certain special steels for commercial purposes, but should also be of general interest as an aid to the study of the reactions between metal and slag. The necessary details are given in Table II.

At this stage it seemed "as if increase of appetite had grown with what it fed on," for the results created the desire to know a little of the effect of other and more unusual bases on the slag and steel, so another special heat was run, using magnesia instead of lime.

It will be seen that the magnesia acts after the same fashion as the lime, with the special characteristics perhaps not quite so well defined.

To throw some light on the rather different effect produced by these basic oxides which do not so readily give up their

TABLE II.—*Lime Charge.*

Time.		Composition of Bath.			Additions.		Consistency of Slag.	Composition of Slag.						
Hr.	Min.	C.C.	Si.	Mn.	Materials.	Cwts.		SiO_2.	FeO.	Fe_2O_3.	Al_2O_3.	MnO.	CaO.	MgO.
5	50	·54	·025	·049	...	...	fairly thin	...	...	...	...	...	...	...
6	0	·53	·031	·055	...	...	thickening	...	...	...	...	...	...	...
6	20	·44	·040	·064	...	...	thickish	...	...	...	...	...	...	...
6	40	·36	·049	·074	...	...	thick	55·45	18·49	1·61	2·02	20·77	2·09	0·89
6	41	...	...	...	lime	3½	...	...	...	...	...	...	...	...
6	50	·30	·051	·081	...	...	thinning	...	...	...	...	...	...	...
7	0	·27	·052	·096	...	...	thin	53·54	16·59	1·36	1·61	19·77	5·96	1·05

TABLE III.—*Magnesia Charge.*

Time.		Composition of Bath.			Additions.		Consistency of Slag.	Composition of Slag.	
Hr.	Min.	C.C.	Si.	Mn.	Materials.	Cwts.		SiO_2	MgO.
3	15	·44	·026	·045	...	...	thinnish	...	...
3	30	·40	·029	·057	...	...	thickening	...	...
3	45	·29	·034	·063	...	...	fairly thick	55·72	3·0
3	50	...	...	...	magnesia	3	...	...	...
4	10	·19	·035	·067	...	...	thinning	...	...
4	28	·17	·037	·074	...	...	thin	54·03	4·0

oxygen compared with the oxides of iron, a charge in which the slag should be allowed to thicken as before and then be thinned with the very oxidizing manganese dioxide was determined on.

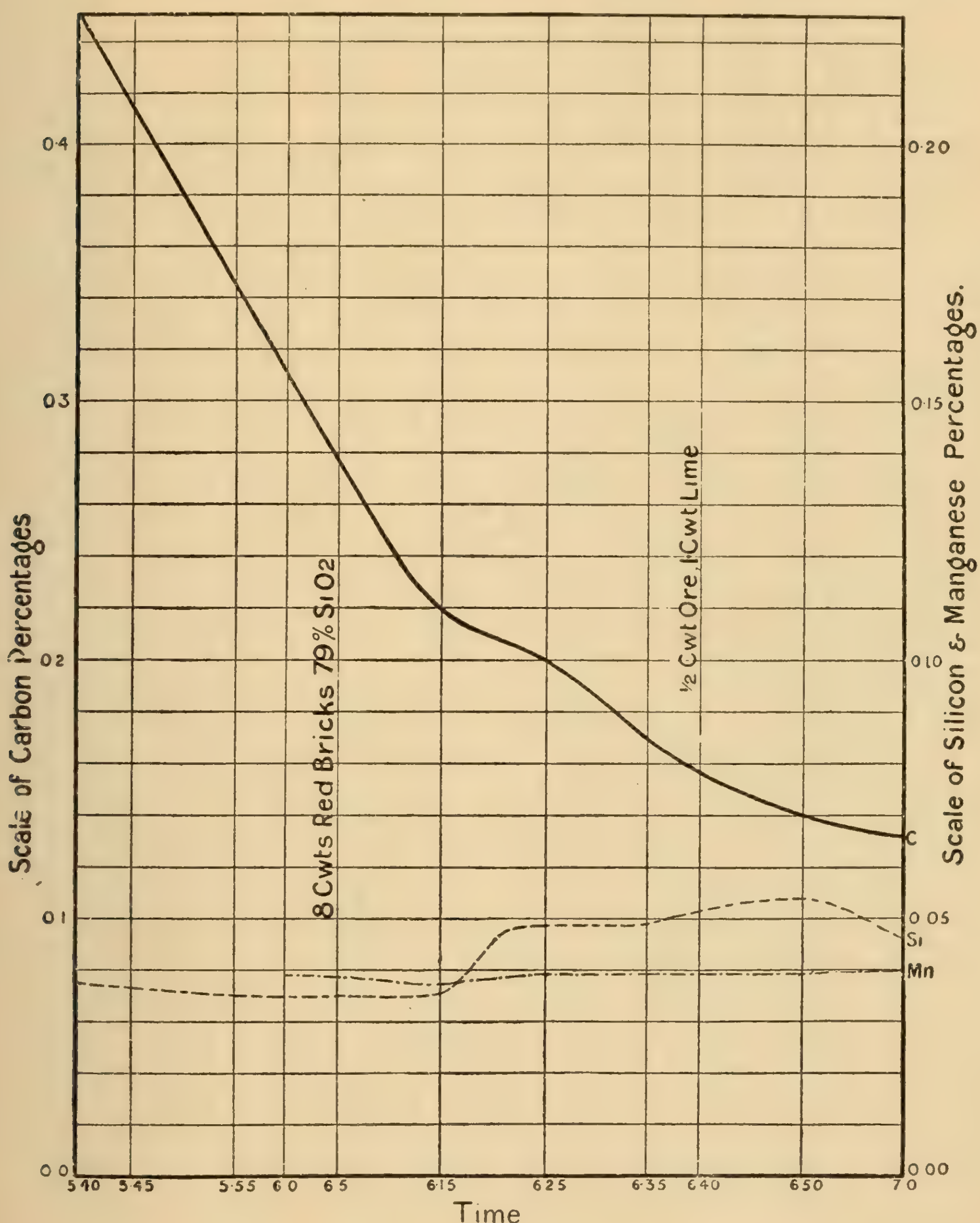


Fig. 1. Red Brick Charge.

In Table IV are given those details of this charge which are of interest in connection with the experiment. No iron ore was added within the limit of the table, the charge was tapped at 3.10 and behaved normally. It will be seen from the analyses

TABLE IV.—*Pyrolusite, 22-ton Charge.*

Time.		Composition of Bath.			Additions.		Consistency of Slag.	Composition of Slag.			
Hr.	Min.	C.C.	Si.	Mn.	Materials.	Lbs.		SiO_2	MnO.	CaO.	MgO.
11	45	...	·20	...	...	...	thin	...	...	...	...
12	30	·74	·05	·104	..	...	thickening	...	...	...	...
1	0	·51	·051	·097	...	...	,,	56·74	16·45	2·96	trace
1	15	...	·063	...	...	...	,,	...	...	...	...
1	30	·42	·069	·09	...	...	thicker	...	...	...	...
1	45	·34	·079	·111	...	...	very thick	57·62	17·48	...	...
1 to 2	48 to 0	...	...	...	MnO_2	440	...	...	...	...	...
2	5	·29	·061	·115	...	...	thinning	56·7	18·14	...	..
2	10	...	...	...	MnO_2	80	...	...	...	...	..
2	20	·25	·052	·109	...	...	thinning	55·8	17·4	..	...
2	35	·19	.066	·124	...	...	thin	57·2	18·4	...	...
2	50	...	·071	...	...	...	thickening	...	...	...	...
3	5	...	(·09) .	...	...	...	,,	64·06	17·97	...	...

that the carbon continued to fall satisfactorily the whole time, that the 520 pounds of the black oxide of manganese thinned the slag and made it less silicious for a short time, but that the new

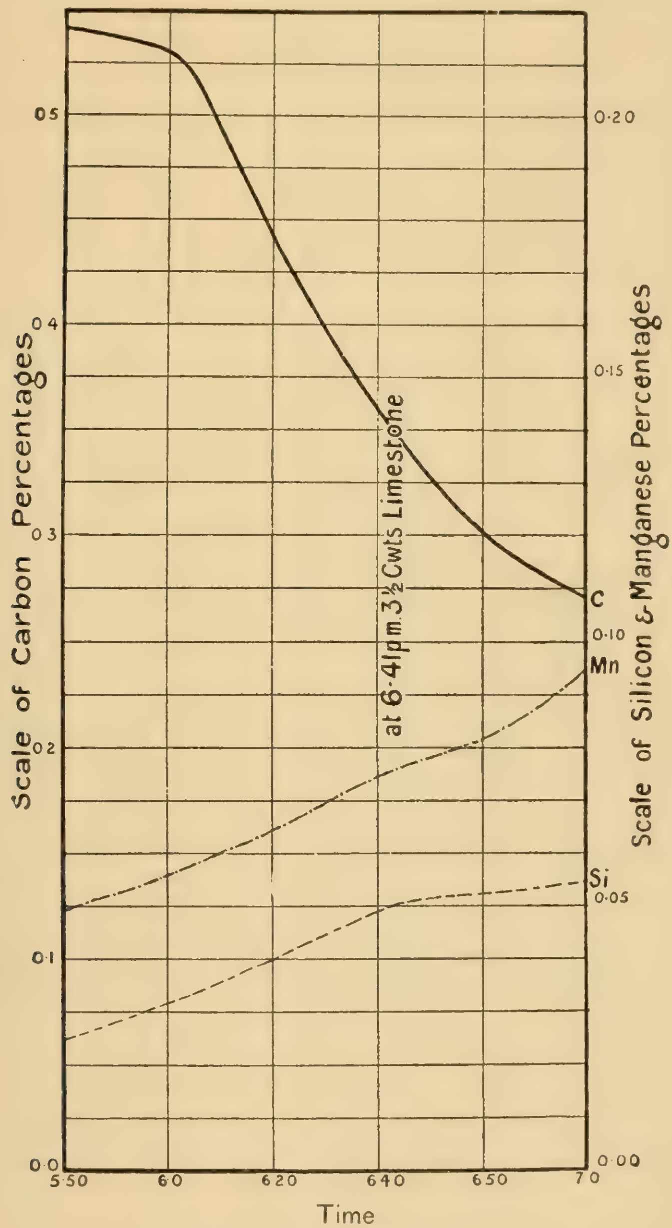


Fig. 2. Lime Charge.

slag quickly helped itself to silica and became viscous and highly silicious. The source of that silica was evident after tapping, for the appearance of the bottom suggested that, as a process for the production of small scale models of the Grand Cañon of

Colorado, inaccurate in detail, but faithful to the spirit, it might be recommended, but as a means of making even special steels it would be a little too exciting. From this it will readily be

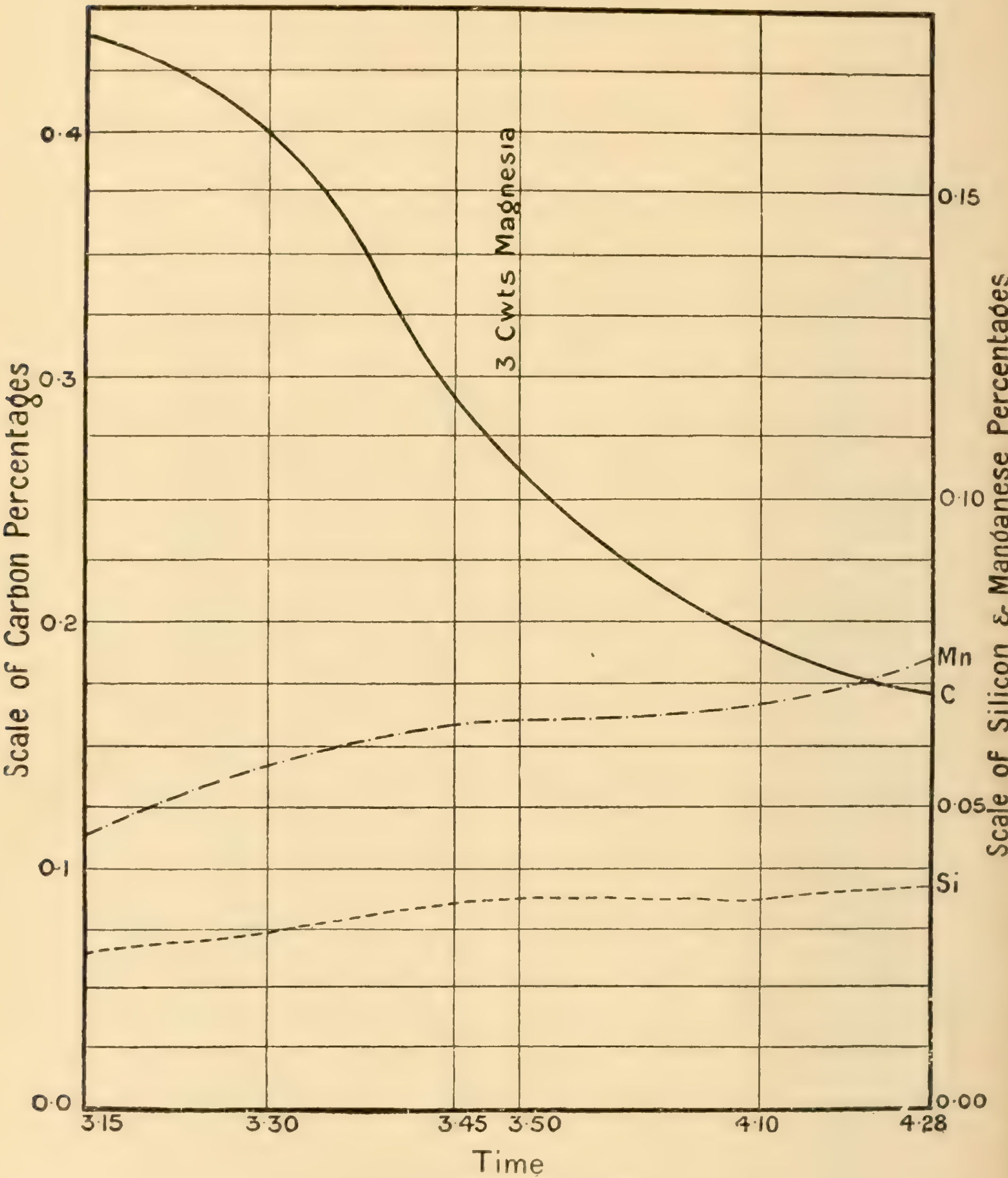


Fig. 3. Magnesia Charge.

understood why the effect of the more basic slags of the last two series have not been tried and are not likely to be, at least by the present experimenters.

An interesting discovery which is at present engaging the

attention of the authors was made during a study of the general notes made of any probable points of interest belonging to the special heats, although these points might not seem to have

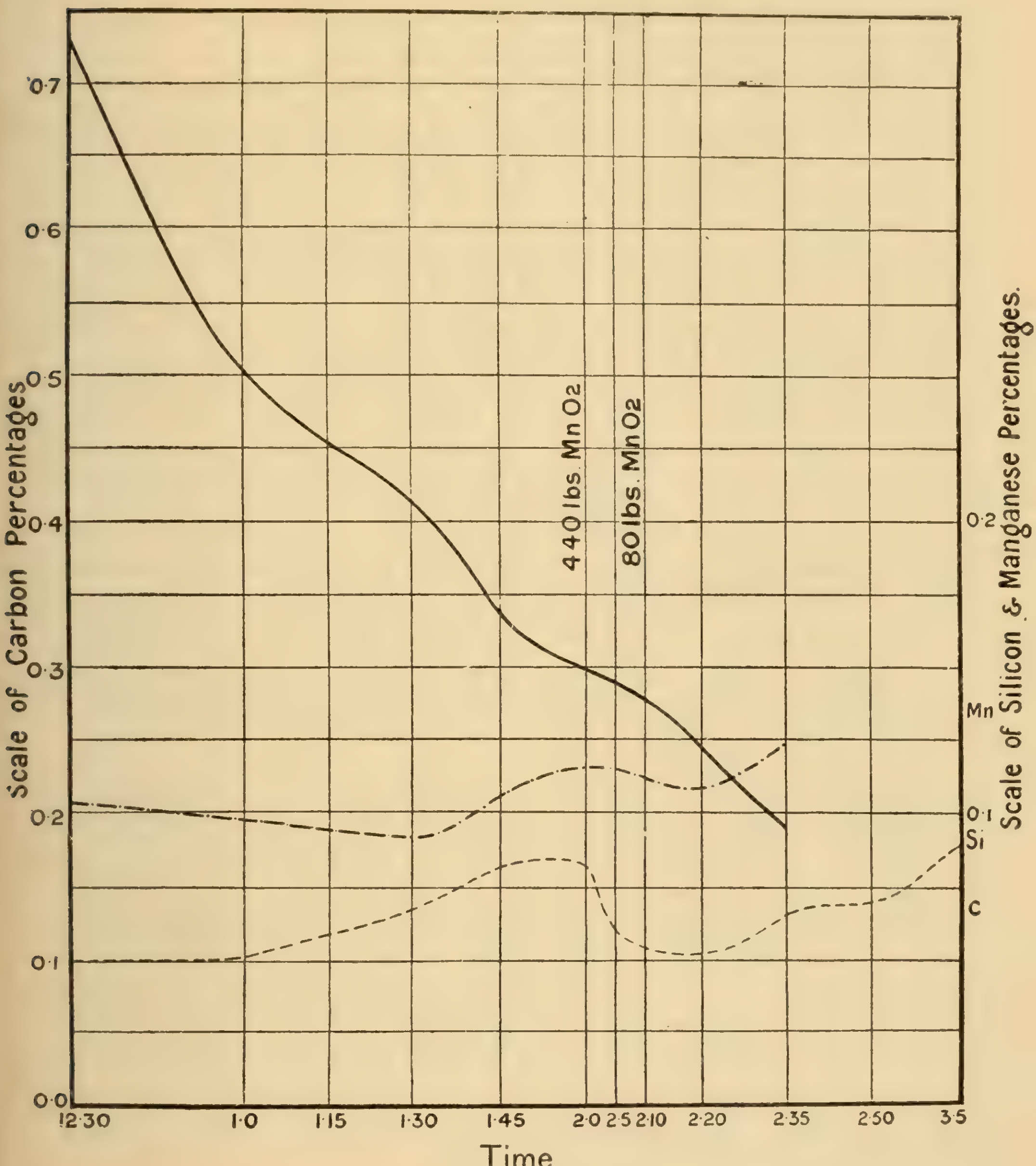


Fig. 4. Pyrotensite Charge.

reference to the more immediate question under observation. It will be remembered that at the May meeting of this Institute Mr. Wahlberg read a paper on some of Mr. Brinell's work on "The Influence of Chemical Composition on Soundness of Steel

Ingots," in which Brinell showed that, in his practice giving certain relative values for silicon and aluminium in terms of manganese, calculating all out to manganese and taking the total, he obtained a number which he named the density quotient, of such a nature that for the same density quotient he obtained the same type of ingot; for a lower quotient one with more blowholes, and for a higher quotient, fewer. Now the general experience of the authors has corroborated that of Brinell, but during the progress of this research they made the interesting discovery that those charges treated to one hour's thickening of the slag required a lower density quotient than that for normal heats, to give a certain type of ingot; charges treated to two hours' thickening required a lower number still; while in a heat run specially fast and finished with a much higher density quotient the ingots corresponded to a lower number.

The following figures, and indeed the whole point raised, are given tentatively as a matter of interest, for it appeals to the writers as being of considerable importance, and they are engaged in following the matter up through this and other channels.

Treatment of Charge	Density Quotient	Type of Ingots
Thickening 2½ hours................	0.814	good
Thickening 1½ hours................	1.00	good
Ordinary	1.35	good

The authors have a theory as to the cause of these differences, but prefer to seek further experimental support before making it public.

Again the authors tender their best thanks to willing helpers; to Messrs. J. H. G. Monypenny, H. H. Slater, M. H. Graham, and J. Kilby, for their very careful analytical work, and to Messrs. John Crowley & Co., Ltd., Meadow Hall Iron and Steel Works, Sheffield, England, for the use of a 25-ton furnace, for the purposes of this research.

METHODS OF PYROMETRY*

IN the organization of the Bureau of Standards, the Director, Professor S. W. Stratton, early recognized the importance to many industries of the question of high temperature measurements and the evident advantages that would result from the use of a uniform and standard scale of temperature, and accordingly a special laboratory has been equipped for the testing of pyrometers, and for the investigation of such pyrometric problems as are of technical and scientific interest. The necesary preliminary experimental work incident to the establishment of our standards, the comparison of available pyrometric methods and instruments, the design and construction of special apparatus required for this work, etc., is in a satisfactory state of development, so that the Bureau is now in a position to standardize almost any type of pyrometer, and to place in the hands of American engineers certified and reliable standards of temperature.

An examination of the present state of pyrometry in this country has established the fact that old and obsolete methods are still too widely used, that the temperature scales in use are based on the results of the experiments of a generation or two ago and are so discordant that a comparison of results between different observers is rendered impossible. The advantages resulting from the world-wide use of one and the same scale of temperature cannot be too strongly emphasized for it alone renders possible the greatest factor in the advance of scientific and technical knowledge, the interchange of experience among men.

With the high degree of accuracy with which temperatures must be controlled to-day, in certain specialized lines of work, this interchange of experience is rendered difficult, if not impossible, where one engineer is perhaps making use of the specific heat of iron, and another, the supposedly constant expansion of some material or the somewhat arbitrarily named color scale.

It is often stated that all that is required of a pyrometer is that it shall always read the same, under the same conditions, and

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* Extracts from an exhaustive article by C. W. Waidner, of the Bureau of Standards, Washington, D. C., in the September, 1904, issue of the "Proceedings of the Engineers' Society of Western Pennsylvania." The author describes all the most important pyrometers.

the question of the actual temperature does not matter. That may be true so far as the actual carrying out of some particular routine piece of work is concerned, but the man who is satisfied with such an instrument will never be in a position to utilize to the fullest extent the experience of his fellow-workers in the same field, nor can he ever do much to advance the knowledge of his profession.

It is one of the great aims of the Bureau of Standards to bring about uniformity in the scales of temperature that are used by scientists, engineers, and technical men, that each may profit to the fullest extent by the experience of the other. Much has already been done in this direction, not only in the fields of temperature measurement, but also in the establishment of other standards, in the field of weights, measures, electrical measurement, light, etc.

Effects of Heat Treatment. — The remarkable effects of the heat treatment of apparently chemically identical specimens of metals was early recognized among the ancients, and throughout their writings we constantly find references to the hardening of metals, to the efficacy of the waters of certain rivers as quenching liquids, and particularly to the difficulty of measuring what they termed the "heat of bodies."*

Thus Geber, in the eighth century, after outlining methods of attaining high temperatures, calls attention to the principal difficulties of the problem "because fire is not a thing which can be measured." In all the centuries that intervened up to the early part of the last century, hardly a single practical step was made toward the solution of this important problem, notwithstanding the fact that the art of working metals and the burning of clays had reached a fair state of development. Indeed the working of iron must have been in a tolerably advanced state among the Romans, for we find references to the existence of guilds, organized, we are told, for the good of the state, occupying a position corresponding to that of the Engineering Societies and Institutes of the present day.

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* A very interesting résumé of the early contributions to the working of steel will be found in a lecture by the late Sir William Roberts-Austen, on the "Hardening and Tempering of Steel," delivered before the British Association, September 13, 1889; see "Nature," Vol. 41, pp. 11-16, 32-38, 1889.

During all this time the methods and knowledge of the metallurgy of iron and steel were entirely empirical. The first great contribution to the exact knowledge of the subject was the discovery of Bergman, of the University of Upsala, who showed in 1781,* that steel differed from iron in that it contained about 0.2 per cent of plumbago, although he called the latter, not plumbago or carbon, but phlogiston, in accordance with the prevailing chemical theories of that time. That this so-called phlogiston of Bergman, that produced such marvellous changes in the physical properties of iron when present in such minute proportions, was in reality carbon, was pointed out by Vandermonde, Berthollet, and Monge, in 1786, in a report to the French Academy of Sciences.

The remarkable changes produced in the properties of metals by the presence of comparatively minute traces of foreign matter, are well emphasized in the statement of the late Sir William Roberts-Austen, before the students of the Royal School of Mines, "that if the thousands of tons of steel in the Forth Bridge had contained two-tenths per cent less of carbon, the material would have been worthless, that thousands of tons of copper would be useless if it contained a trace of bismuth, and that the eighty millions sterling of gold coin would have crumbled away if it had contained one-tenth per cent of lead."

Important as was an exact understanding of the chemical side of the problem, not alone of the effects of carbon, but of the addition of other elements, such as silicon, manganese, tungsten, nickel, etc., to iron, it was not until due attention was given to the other important factor of the problem, the *heat treatment*, that the metallurgy of iron and steel advanced with ever increasing acceleration until to-day it has assumed the most important place in the scale of the world's economy, and has displaced an age of agriculture, for centuries the most important pursuit of man, by an age of steel.

It is hardly necessary to cite examples of the very different physical properties that can be imparted to one and the same specimen of steel by varying its heat treatment, properties so dissimilar that they differ more from one another than they do from those of many entirely different chemical elements.

* "Opuscula Physica et Chemica," Vol. III. De Analysi Ferri (Upsala, 1783).

An intelligent application of the proper heat treatment of steel necessitates a knowledge of the temperature, whether estimated by the experienced eye of the workman or by the indications of an instrument called a *pyrometer.*

Importance of Temperature Control. — For a long time every requirement as to the proper temperature at which the processes of hardening, tempering and annealing should be carried out was met by the trained eye of the workmen, who became remarkably skillful in the estimation of temperature. But the recent development, and wide application to the most varied problems, of certain high carbon and special steels, have rendered it necessary to know the temperatures at which these operations are carried out far more exactly than they can be determined by even the most highly trained eye. Thus, in many cases, a variation of 15° C., or even less, is sufficient to determine the failure or suitability of a given sample of steel for the particular work for which it is intended.

Where such an exact knowledge of the temperature is essential to success, its estimation by the eye is always attended with difficulties and uncertainties, being dependent on so many circumstances, such as the amount of light in the room, the location and accessibility of the work, the physical condition of the observer, the fatigue of the eye, etc. It therefore becomes necessary to substitute for a more or less happy series of guesses, the more scientific and certain procedure, viz., the measurement of temperature by means of a reliable pyrometer. The two great advantages resulting from the use of the pyrometer, which are at once evident are:

1. That when once the proper method of working a particular grade of steel, or of burning a particular sample of pottery, or whatever may be the problem at hand, has been found, that operation can be indefinitely repeated, thus rendering possible the exact *duplication of product.*

2. That the reproduction of any particular product is no longer locked up in the experience of a few workers but becomes a matter of permanent record, that can be consulted at any time, and which renders a repetition of experiments unnecessary with each new order for that particular product.

In addition to the economics resulting from the many applications of the pyrometer to the working of metals, the production

and annealing of glass, the manufacture of ceramic products, the operations of galvanizing, the control of chemical transformations, ranging from ordinary temperature to the white heat found in the heart of the great steel blast-furnaces or the still hotter electric furnaces, the pyrometer has already greatly enlarged our knowledge of the molecular changes that take place in a mass of steel in the various operations to which it is subjected in working, and its application to the solution of metals in metals* has materially added to our ideas of the molecular complexity of matter. The pyrometer alone can give us an insight into the character of the enormous internal stresses in a mass of iron and steel that are caused by the various operations of hardening, forging, rolling, etc., and by the effects of temperature lag, and consequent lag of the carbon change, of the interior of a mass of steel relative to the surface.

Without venturing into the much disputed territory of the theories of iron carbon compounds and much less to express an opinion thereon, it may be of interest to call your attention to one or two illustrations that emphasize the use of pyrometric methods in investigations on the metallurgy of iron and steel, and show the important rôle of temperature treatment on the character of the resulting product, and this irrespective of whether the carbon modifications or the allotropic iron changes play the more important rôle.

For a long time it was thought that the widely different properties of iron, commonly known as wrought iron, cast iron, and steel, could be explained by the mode of existence of the contained carbon in the forms of annealing, carbide, or hardening carbon respectively. Experiment, however, has shown that by rapid cooling from a certain temperature soft steel can be obtained in which the carbon is present in the form of hardening carbon. It was at this point that Osmond took up his magnificent investigations in which he sought for evidence of molecular changes by studying the cooling of various specimens of iron and steel, making use of a Le Chatelier thermocouple for this purpose.

In the cooling curves for low-carbon steel it will be observed that there is an arrest in the rate of cooling at about 725° C. and a second arrest in the neighborhood of 650° C. Osmond has associated the first change, or so-called "critical point," with a change

* See Heycock and Neville, "Chem. Soc. Jl.," Trans., 1890.

in the molecular state of the iron, and the second "critical point" with a change in the mode of existence of the carbon. That the first critical point is probably due to a molecular change in the iron, independently of the presence of the carbon, seems to be established by the cooling curve for pure electrolytic iron which shows a sudden arrest in the cooling in the neighborhood of 865° C. In the cooling curve for high carbon steel the two critical points have merged into one at about 675° C., where it takes about 75 seconds for the specimen to cool through 6.6° C. The physical properties of the steel depend in a marked degree on the temperature at which sudden cooling begins; thus, experiment has shown that it is impossible to harden the steel by sudden cooling below the second critical point.

Such experiments led Osmond to his well-known allotropic theory of steel, in which he sought to explain the observed phenomena, not alone by the carbon changes, but also on the assumption that iron could exist under different molecular conditions. This view was not unique in attributing this quality to iron, but is indeed strengthened by the analogy of carbon and sulphur. The latter it is well known can exist in two states, one the well known hard yellow form, the other the brown and viscous form which readily passes over to the more stable form. Similarly carbon can exist in the diamond and graphite forms. It has long been known that by the application of high temperatures it was possible to pass from the diamond to the graphite form. The inverse process has only recently been carried out by Moissan, by making use of the intense heat of the electric furnace and the great pressure exerted by sudden cooling of a layer of iron surrounding the graphite.

As the temperature of steel is raised a point is reached at dull red heat when it suddenly loses its magnetic properties. This is found to be coincident with the carbon critical point referred to above. It is interesting to notice that the cooling curve of manganese steel does not show this critical point, and as it is in a non-magnetic state at high temperatures, and does not pass through a critical point, it might be expected to remain non-magnetic at ordinary temperatures. This is approximately verified by experiment as manganese steel is only feebly magnetic.

Numerous other interesting changes in the physical properties of steel take place at this critical point. Thus Gore showed

that an iron wire on cooling shows a momentary elongation at this point; Barrett, that it suddenly glows, a phenomenon which he called "recalescence." Pionchon showed that iron undergoes large changes in its specific heat in the neighborhood of the critical points, and Le Chatelier, that there were marked changes in the thermo-electric properties.

The changes in volume accompanying these carbon changes, which take place at different times throughout a large mass of cooling steel, must set up enormous internal stresses that cannot but have a marked influence on the character of the product. A systematic investigation of the lag of the carbon changes at different parts of the cooling mass, by means of a thermo-electric pyrometer, would do much to give an insight into the magnitude and character of these internal stresses, and serve as a guide as to the best method of working the product for the purposes at hand.

This example is perhaps sufficient to emphasize the importance of pyrometric methods in the study of the metallurgy of iron and steel, and in the development of a theory to explain the observed phenomena.

THE SMALL CONVERTER PROBLEM*

By ARTHUR SIMONSON

THE Tropenas Steel Process has been the subject of considerable discussion during the past year on account of its growing popularity, and the fact that two United States government arsenals have adopted it with the result of raising the general standard of specification for steel castings. Several contributions to the literature of the small converter have been made recently, including papers before two Foundrymen's Associations, which have been fully reported in the technical press.

Although the general subject of small converters would appear to have been fairly well ventilated, the nature of the discussions at the reading of the above papers, and the amount of correspondence that has taken place with the writer shows, what is quite natural to expect, that there are many points omitted in a

* "The Foundry," November, 1904.

prepared paper that appeal to practical men and on which they wish specific information. At the same time the nature of some of the queries indicate that, while considerable interest is aroused, there is a conspicuous lack of a general knowledge of the subject.

Probably the most important question raised is the one relating to the market which is open to the product. First of all, let us consider what the product is, and in making these statements let it be clearly understood that they are merely the results of long and current practice and can be duplicated with every plant erected if the process is carried out scientifically by experienced people. The usual commercial product then is genuine high-grade steel of composition identical with the best open-hearth steel, high in tensile strength and ductility, sustaining from 60,000 to 80,000 pounds per square inch tensile strength, with an elongation of from 25 to 35 per cent on two inches. The bending test is from 90° to 180°. It is capable of being run into the lightest and most intricate shapes, is perfectly sound and free from blowholes and can be welded.

Outside of this general grade of steel every class of special steel is made with regularity and convenience surpassed by no other process. Unfortunately for the good reputation of the small converter, owing to its comparatively recent advent, it is in some cases being run by inexperienced persons, and there is being put on the market as the best product of the small converter some very bad castings indeed. At the same time semi-steel and other materials with curious names and still more curious properties, are being sold and bought very extensively as steel. The first impression of a buyer when hearing of the Tropenas steel for the first time is that it is only another of these hybrid metals or modified cast iron, and salesmen are confronting this all the time. Of course the first piece he sees if submitted to any kind of a test, physical, chemical or microscopical, is convincing, but the trouble is that the ordinary buyer of small steel castings does not go into it so deeply and if he finds that the castings are more or less malleable and cut something like steel, he is satisfied. Tropenas steel is not semi-steel, and any comparative test will prove it.

The chief points of recommendation are the regularity of the material, the cheapness of the plant and the convenience of handling. This in spite of statements that have appeared to the effect that a Tropenas plant is costly and the process wasteful.

These statements will be shown to be erroneous in the course of this article. It is to-day an indisputable fact that a small converter plant manufacturing castings for the trade is a paying proposition if handled by men of experience in the general branches of steel foundry practice. It is not in the cost of the fluid steel in the ladles that the cost of production can be materially cut, because on the same tonnage basis Tropenas steel is made as cheaply as open-hearth steel. But in its subsequent handling, the cost of molding, cleaning, and the removal of heads and gates there is room for a great deal of ingenuity and good management that is conspicuous by its absence.

In discussing the subject of the market we have to consider the different means available for producing steel castings and how nearly they meet the total requirement. What is their relative cost, what are their shortcomings, and are they all, or any of them, overcome by the small converter? Above all, how does the cost of the small converter compare with the other means at our disposal? The bulk of steel castings in use at the present time are made either in the crucible or the open-hearth process. The crucible process is purely a melting process, no refining is accomplished, and it is necessary to use the finest raw materials and those which are exactly suited to the composition of the steel required. You simply get out of the crucible the approximate average of what you put in, with slight losses or gains in certain elements.

Whilst a crucible plant is not very expensive, its cost of maintenance is high and the crucibles which are useful for very few heats are quite costly. This coupled with the necesssarily small output makes crucible castings very expensive. There is no doubt that the crucible can make the very best castings and very small ones, and therefore when it is a question of obtaining very small, high-grade, genuine steel castings, and price is a secondary matter, this process meets the requirements. Its disadvantages are exceedingly high prices, small output, and the castings as a rule are comparatively hard. The open-hearth process holds an unassailable position for the manufacture of almost every class of castings, its capacity is becoming greater all the time and the quality of the material produced is very high. But the cost of an open-hearth plant is enormous, it must be kept going continuously to its full capacity to be economical, and it is quite un-

suited to the manufacture of small castings. We have, then, in a nutshell, the open hearth which is cheap but unhandy, and the crucible which is very convenient but costly. We need the happy medium, and the small converter supplies it. The castings are cheaper than crucible, but as a rule slightly dearer than open hearth, the capacity of the small converter is much greater than the crucible and it can make any castings which the open hearth can. Obviously then there is a very extensive market.

The next point on which a good deal of discussion has arisen is melting stock. It seems to be the impression of some people that suitable melting stock is difficult to obtain. This is not so. The pig iron used is low phosphorus pig, and there is always plenty of it in the market, and silicon over two per cent and under four is not hard to obtain. The writer has never experienced any difficulty in obtaining all necessary pig iron, and by a judicious mixture of two or three kinds it is possible to make any desired composition. The amount of steel scrap that may be melted in the cupola to give good results has been asked for and many opinions expressed. The fact is that any amount may be used under certain conditions, and these conditions alone must determine the amount. What is the object in melting steel scrap in the cupola? It must be either that steel scrap is cheaper than pig iron, or it is used in order to use up defective castings, risers and gates. If the class of work or long experience of the operators enables them to make very few defective castings and cut down the risers and gates to a very small percentage, and if foreign scrap is high a small proportion should be used and vice versa. It is a question of economics, there is no technical difficulty in using up to fifty and even sixty per cent. The writer is at present manufacturing a class of work which makes so little scrap it is impossible to supply the necessary amount and foreign scrap is used continuously. It is better as far as possible, on account of the problematic and often questionable quality and composition of foreign scrap, to make the plant self supplying, and in good practice the scrap made should not exceed 25 to 30 per cent of cupola charges.

The only thing to bear in mind is that the metal tapped out of the cupola, which is to be put into the converter and blown, must have a chemical composition varying only between certain limits. It does not matter what the cupola charges are made up

of so long as they give this result, and it is for each operator to decide what will be the cheapest way for him to make up those charges.

The next point of interest, and one of great importance, is the one relating to wastes and losses in manufacture. It has been reported as the experience of different parties using small converters that the unreclaimable loss, that is the losses by oxidation in cupola and converter, runs as high as 30 per cent, to say nothing of the amount used as shrink heads and gates. It is apparent that under such conditions the process could not possibly pay, and as any such losses are most emphatically not necessary to its successful working, it only remains to say that any operator making such losses should either improve quickly or else gravitate out of that particular foundry.

The loss in a small cupola, such as is commonly used with the process, from 30 inches to 40 inches diameter is about five per cent, or not much either side, the causes of which are too well known to need any recapitulation. The losses in the converter consist of about six per cent of carbon-silicon and manganese *purposely burnt* out of the metal in order to raise its temperature to the very high point necessary to run the small sections and about four or five per cent of iron consumed during the process. The carbon-silicon and manganese in the pig iron constitute the fuel and nothing but atmospheric air is blown into the converter. Further waste and expense may be caused in the method of adding the final additions used to recarbonize the steel to the desired point. The common method is to melt the final additions in a crucible or small cupola or to heat it to redness in a furnace. But if the process is handled properly the steel will be hot enough to melt any amount of final additions commonly required by adding in the cold state and thus getting the full benefit without any loss.

It is said that considerable loss occurs through the projection of iron from the mouth of the converter during the blow by the violence of the reaction taking place within, and it is said that a patent has been granted on a converter with special tuyères intended to be opened when any violent reaction takes place and by blowing these projections downward and against the side of the converter prevent them from blowing out of the mouth. This seems like using the pound of cure when an ounce of prevention

is not only better but easily available. If the composition of the metal is right and the operator knows his business there will be no projections of iron at the converter mouth, but only small globules of slag and these not more than enough to fill a bucket in the course of a blow.

The matter of durability of converter linings is a question that has caused a good deal of discussion, because it is apparent that a lining which will stand the intense heat and the chemical action must be very refractory and pure. The chief cutting action on the lining is caused by the oxide of iron formed during the blow and its greatest effect is felt in the neighborhood of the tuyères where it is produced.

The converter may be lined in a variety of ways and with numerous forms of material, although all are of similar composition. In Europe large special shaped blocks of high grade silica brick are used and by this means converters can be very quickly lined and the objection of having many joints between the bricks is reduced as much as possible. The disadvantage of this method is the cost of special bricks and the fact that when making repairs it is necessary to cut away sometimes a good quantity of unburnt or partially burnt brick to fit in the new ones, and this means waste.

In America, where the converters are lined with brick, the common square, arch and wedge are used and the lining is generally put in double, so that when the first row is burnt out a new one is put in. This method has the disadvantage of being slow, it makes very many joints and as the lining does not burn out evenly an amount of good brick has often to be cut out in making repairs. By these methods a converter may be made to last 1,000 or more blows without relining completely to the shell, and the tuyères will have to be renewed every 100 or 150 blows, depending on what opportunities offer for repairing them. There is another method of lining which is probably the cheapest and most economical of all. That is to make the lining by ramming a silicious material around a collapsible metal form, which is afterwards withdrawn through the mouth of the vessel. The tuyères may be also formed of the same material integral with the lining by placing tubes in the correct position and afterwards withdrawing them. Repairs are then made by putting in the form and ramming in the material against the face of the exist-

ing lining without having to cut and waste anything and there are no joints.

The following are some interesting and pointed questions that have been asked the writer. As they have probably occurred to many others it would seem that an attempt to answer them here would not be out of place.

(1) Will the metal run small gated patterns such as are made at present in malleable iron? There are undoubtedly many patterns made in malleable iron that it would be practically impossible to run in steels under any conditions. The writer has run strips $8 \times 1\frac{1}{2} \times \frac{1}{8}$ inches as a test for fluidity and from this an idea may be gained as to what can be done.

(2) What is the greatest difficulty in the process?

In answer to this it may be said that there is no greater difficulty in handling it than in any other steel-making system. There are no gas producers, and no regenerating system and all the training that is necessary is in the ordinary requirements of a foundry — the making of cupola mixtures by chemical analysis and the judging of the flame by actual experience gained by watching a number of blows alongside of some one who is thoroughly posted and can point out the indications.

(3) What is a good average production of steel per day in working regularly? What is the maximum production that might be kept up say for two or three days?

With a plant consisting of one converter of two tons capacity and blowing every day, making the repairs to the lining at the week end, about six blows a day, equivalent to about 12 tons of steel, would be a very fair production. For two or three days it would be possible to make 10 or 12 blows a day. If such a quantity is required it is much better to have two or three converters as it is then possible to run two converters at the same time and have one always under repair. With three converters an output of 600 tons per month of finished castings is easily available.

(4) Can the Tropenas system be run successfully with converters of 1,000 to 2,000 pounds capacity?

Converters of that size have been built and run as successfully as could be expected considering the physical difficulties of handling such small quantities of molten metal. Any one familiar with steel foundry practice will appreciate the fact that such

small quantities of steel have to be handled so quickly that it is not convenient. No matter how hot the steel is to commence with, it soon chills. Practically the same number of men would be required to handle it, repairs are more difficult to make, and the small output renders it uneconomical. The two-ton vessel has been found to be the most convenient size and greater output is secured by increasing the number of vessels.

USE OF MANGANESE IN CUPOLA OR LADLE*

By N. W. SHED

THE value of manganese in many castings is unquestioned. It makes a closer grain and prevents the cutting action of many corrosive substances. Few of the ordinary pig irons go above one-half of one per cent in manganese and to get a large percentage in the casting it is necessary to add a high manganese pig or spiegel to the cupola charge or else add ferro-manganese in small lumps to the metal as it runs into the ladle. With hot metal several hundred pounds may be added in this way.

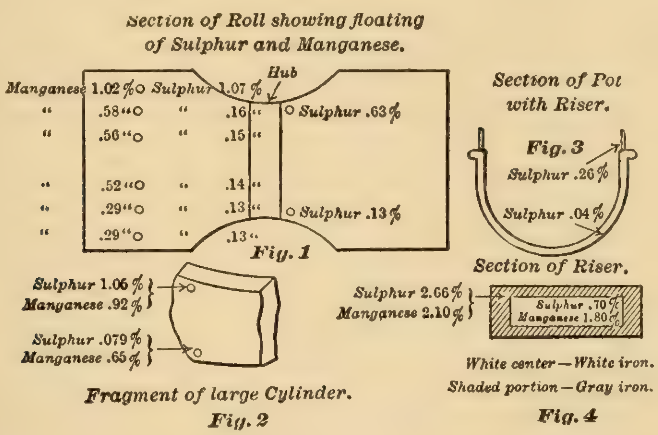
Foundrymen have usually said that it made little difference whether the manganese was added in the cupola or in the ladle, provided the ferro-manganese did not cost much more than the high manganese pig for the amount of manganese added. The question of cost will not enter the discussion, for there is very little difference in expense between the two.

To test the question whether it makes any difference in the castings, a number of heats were run by adding high manganese pig to the cupola charges, and a corresponding number were run by adding ferro-manganese in the ladle. When ferro-manganese in large quantity, 200 to 300 pounds to the ladleful, was used, it was noticed that the manganese would combine with the sulphur present and carry a large amount of it to the top of the ladle. It would be possible to skim the ladle and thus reduce the sulphur considerably. The same thing is true in casting; the melted manganese seizes the sulphur and floats it to the very top of the casting.

This was proved in many instances; the most remarkable

* "The Iron Trade Review," October 13, 1904.

one was the difference between the bottom and top of a 2,000-pound roll. The surface of this roll was difficult to machine and drillings made from the top of the roll showed 1.07 per cent in sulphur and 1.02 per cent in manganese. The roll was afterward broken and drillings made at intervals of a few inches from the top to the bottom. The results of the analysis of these drillings are shown in Fig. 1. The iron used in this roll averaged 0.05 per cent sulphur.



In pouring heavy cylinders the same thing is noticed. Fig. 2 is a sketch of a fragment of a cylinder. The upper edge of the piece showed sulphur 1.05 per cent with manganese 0.92 per cent. Ten inches lower the piece showed sulphur 0.79 per cent with manganese 0.65 per cent. Again in pouring large pots the risers will often show 0.26 per cent sulphur while the body of the pot will show but 0.04 per cent sulphur as illustrated in Fig. 3.

On one or two occasions it was observed that these risers would show white iron in the center with well defined gray iron toward the surface as illustrated in the sectional view, Fig. 4. As this was a curious exception to the general rule, portions of each iron were tested for sulphur and manganese. The white interior showed 0.70 per cent sulphur with 1.80 per cent manganese. The gray exterior showed 2.66 sulphur with 2.10 per cent manganese. When it was noted that this metal, normally, would not run over 0.06 in sulphur, this separation of the metalloid in the riser is remarkable.

These instances might be multiplied, but they suffice to prove that ferro-manganese added in the ladle will float the

sulphur to the top of the casting. On the other hand, when castings are made by adding high manganese pig to the cupola charges, no such action of the manganese is observed and there is no difference between the bottom and the top of the casting in sulphur percentage.

To avoid such irregular metal with its attendant hardness it would be well to abandon the practice of putting large amounts of ferro-manganese in the ladle. Small amounts of manganese to bring the manganese up 0.10 to 0.20 per cent would do no harm and would correct any tendency to oxidation, and would give a closer grain to the casting.

At present high manganese pig, two to three per cent manganese, can be bought from $1 to $2 per ton higher than ordinary pig iron, and by using 10 per cent to 20 per cent of this in a cupola charge, the iron is raised in manganese without the bad effect of floating the sulphur. In pouring high manganese metal a very beautiful display of metal in motion is noted. The surface seems to be covered with rosettes which continually change their position. Some speak of it as an oily film playing over the surface. It is probably caused by the action of the air on the film of manganese metal, but no explanation of it has come to the writer's notice.

In connection with the use of manganese it would be proper to state that most of the wonderful improvers of iron are nothing but alloys of manganese. Some contain considerable silicon, some have a little aluminium. A few ounces are supposed to make a good iron out of the poorest, and the promoters talk about life-giving effects, regenerating influence and renovating properties. The effect is due to the manganese contained in the alloy.

A sample of one of these regenerators selling for 30 cents a pound was recently tested at the Foundryman's Laboratory. It contained about 20 per cent of manganese. A spiegel of the same percentage could be bought for less than two cents per pound and would have the same effect.

If ferro-manganese were added to the cupola charge it would doubtless be better for the metal, but there would be danger of the strong cutting action of the manganese upon the cupola lining and also a great waste of manganese by oxidation at the tuyères. For these reasons the use of high manganese

pig in the cupola is suggested as the best practice. In air furnace castings the ferro-manganese has the same action as upon cupola metal and nearly all the manganese should be charged in the air furnace as high manganese pig.

[The experiments referred to were carried on by the courtesy of the Buffalo Foundry Co. which offered the use of its large ladles for the purpose. The ladles carried ten tons of iron in most of the trials. The air furnace pouring over ten tons was also used, as well as the cupola. As the cupola metal made by this company never runs above 0.07 in sulphur, this segregation of sulphur at the top of the casting was remarkable, and the Buffalo Foundry Co. was interested in finding the cause. — EDITOR.]

THE MANUFACTURE OF STEEL CASTINGS*

History, Development and Present Practice of the Art of Making Structural Machine Elements of Steel Castings

THE growth in the use of steel castings for machine construction has been a notable element in mechanical progress during recent years, and it is a curious fact that, in spite of the importance of the subject, but little available information exists as to its practical technology. For this reason the papers of Professor Bernard Osann, in recent issues of "Stahl und Eisen," form a welcome contribution to the literature of the subject, and demand review at length. The remarkable display of steel castings at the recent Düsseldorf exposition furnish numerous illustrations of what has been done in this department of work, and add materially to the value of the papers.

Attempts to make steel castings followed close upon the development of the open-hearth process, but the difficulties in the way caused progress to be slow at first. About 1872 attempts were made to cast screw propellers in steel, and gradually sufficient experience with the practical details was acquired, so that after about ten years the use of steel casting for machine parts began to meet with approval, and at the present time, and espe-

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* "The Engineering Magazine," October, 1904.

cially since the development of the electrical industries, the material has come into most extended use. Indeed, it is fair to say that without the ability to use steel castings the present development in machine construction would have been impossible. Cast iron, while useful for many purposes, is of but limited application, because of its low tensile strength, brittleness, variability, and low elasticity, while forgings of iron or steel are debarred from many uses, both because of the prohibitory cost and because of the impracticability of forming it into the irregular shapes possible with a material which can be cast in a mold. Doubtless the development which has been made in the use of steel castings is largely due to the demands which have thus been made for a material which should have the good properties of both materials and the defects of neither.

Among the early difficulties encountered in the use of steel castings, the most troublesome were the frequent occurrence of blow holes, the appearance of hot and cold cracks, and the problems of shrinkage, but as a matter of fact these are really the same questions which should be considered in connection with cast iron, except that their greater frequency and extent with steel has made them more conspicuous.

In making steel castings the influence of the high temperature at which the metal is poured upon the refractory material of the mold must be taken into account. This requires great care to be exercised in the selection of the sand and clay for the mold and corresponding precautions in drying and baking. Such molds necessarily offer a greater resistance to the shrinkage of the casting, and since the shrinkage of steel is much greater than that of cast iron, frequently more than twice as much, cracks are formed in the hot metal as it solidifies, these being called hot cracks in distinction from cold cracks which appear in the finished casting.

The tendency to form blow holes may also be traced to the great shrinkage of the steel, and hence the best method of prevention is to provide ample facility for the mass of the metal to follow the movement of contraction. This is done by providing a number of risers at the points where the best connection with the body of the mold can be effected, besides furnishing a much more liberal sinker head than would be considered necessary for cast iron. By such means, as well as the use of proper precau-

tions to prevent the exterior from cooling too rapidly, the blow holes may be prevented.

A most important portion of the work in the production of satisfactory steel castings, however, must be done, not in the foundry, but by the designer in the preparation of the form and character of the piece to be cast. In this department of the work the same general considerations hold good as in the foundry. The great extent of the contraction of the metal, sometimes as much as three-eighths of an inch to the foot, or more than three per cent of its length, must always be kept in mind. It is evident that unequal shrinkage will lead to the formation of cold cracks and cause internal strains, while uniform shrinkage, even if great in total amount, will not produce these effects. It is therefore most important to design the work in such a manner as to avoid great variations in the masses of metal, keeping uniformity of section as much as possible.

By distributing the material in the form of thin plates, reinforced by ribs of the same thickness, and adopting cellular construction for the parts where the greatest strength is necessary, it is altogether possible to permit the various parts to be kept at nearly the same temperature during the operation of casting and cooling, so that shrinkage strains and cracks may be almost entirely avoided. It is also important that sharp corners and angles are avoided, large fillets and easy curves being employed, since any sharp angle partakes of the nature of a nick and forms a ready point for the origin of a crack. It is not too much to say that a large part of the success which has been attained in the use of steel castings has been the result of the education of draughtsmen and designers at these points, while much of the trouble has been due to the neglect of just such simple precautions.

In the manufacture of steel castings it is important that care be taken in the character of the metal. Especially is it important that the phosphorus, sulphur, and copper be present only in the smallest quantities, and it is only with the best material that the best work can be expected.

Professor Osann illustrates his papers with illustrations showing a number of important steel castings, these including stern posts and rudder frames for large vessels, bed plates for marine engines, heavy gearing, dynamo frames, armatures, and

details, besides numerous portions of machines of all kinds, many of these having formed portions of exhibits at Düsseldorf. These include pieces from less than a pound in weight up to 50 tons or more, forming examples of actual work, and not merely produced for exhibition purposes, and fully demonstrating the extent to which steel castings are being applied in practical engineering work.

ABSTRACTS *

(*From Recent Articles of Interest to the Iron and Steel Metallurgist*)

The Influence of Carbon, Phosphorus, Manganese and Sulphur on the Tensile Strength of Open-Hearth Steel. H. H. Campbell. The Iron and Steel Institute, New York meeting, October, 1904. 20,000 w., 12 illustrations and 19 tables. — The author describes an exhaustive series of tests made to ascertain the influence of carbon, phosphorus, manganese and sulphur upon the tensile strength of open-hearth steel, with a view of writing a formula by which to calculate the strength of such steel from its chemical composition.

The investigations were made at the works of the Pennsylvania Steel Company, Steelton, Pa.; the ingots from which the tests were made were six inches square in every case; they were heated in the same furnace and forged at the same hammer into billets of the same size; these billets were reheated in the same furnace by the same men and rolled in the same set of rolls into $2 \times \frac{3}{8}$-inch bars of about the same length. These were cooled under the same conditions, broken in the same machine by the same men, and analyzed in the same laboratory by the same staff. Some ten years ago the author proposed the following formulas as the results of an extensive series of tests:

For acid steel: 38,600 iron + 1,210 carbon + 890 phosphorus + R = ultimate strength.

For basic steel: 37,430 iron + 950 carbon + 1,050 phosphorus + 85 manganese + R = ultimate strength.

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* Note. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" \$1.00, "F" \$1.20, "G" \$1.60, and "H" \$2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

The iron, carbon, phosphorus and manganese are expressed in units of 0.01 per cent, and R, as well as the ultimate strength, in pounds per square inch. R is a variable, to allow for heat treatment. In angles and plates, about three-eighths inch or one-half inch in thickness, and finished at a fairly high temperature, R is zero.

In this formula, Fe, 38,600, represents the value independently determined for pure iron. From a mathematical standpoint there can be no objection to including iron as one of the factors in the problem, but practically there are the following reasons to the contrary:

1. There is a doubt whether the real basis of strength varies with each increase or decrease in the total metallic iron. It may be that the datum-plane is the same, whether the steel contains 99.6 per cent, or 99.1 per cent of iron.

2. Since the iron is determined by difference, all the errors in determining carbon, manganese and phosphorus, as well as the total contents of sulphur, copper, silicon, and other elements, may make a composite error of no small moment; and this is all embodied in the figure representing iron.

3. The range of variation in the percentage of iron is not sufficiently great to give a good working basis.

Notwithstanding all these objections to the methods of determination, the derived formulas given above have been of the utmost practical importance. They have been applied to every heat of steel made by the Pennsylvania Steel Company for the last ten years; and there has rarely been in the ultimate strength of soft steels, a difference of more than 2,500 pounds per square inch between the result given by the formula and the record of the testing machine. In most cases the error has been much less than 1,500 pounds; and so great is our confidence in the formulas, that chemical determinations are always repeated when they are not confirmed by the machine test. In view of such an experience in every-day commercial work, it would be rash to say that the method is entirely wrong, or that the formulas do not represent actual conditions.

To check the first investigation, two entirely new series of bars were collected; one of nearly seven hundred from acid heats, and the other of eleven hundred from basic heats. Duplicate determinations were made on each bar for phosphorus

and manganese. The carbon was determined in three ways: (1) the bar was analyzed by combustion (duplicate tests being made in case of doubt); (2) the bar was analyzed by the color test; (3) a piece of the ingot from which the bar had been made was cut off at the hammer, and analyzed by the color test.

Three bars were pulled on each heat, two on one testing machine and one on another. The figure used is the average of the three bars.

The conclusions from the results of this second investigation are as follows:

Carbon. — In acid steel each 0.01 per cent of carbon strengthens steel by 1,000 pounds per square inch when the carbon is determined by combustion. The strengthening effect is 1,140 pounds for each 0.01 per cent as determined by color, owing to the fact that the color test does not determine all the carbon present.

In basic steel each 0.01 per cent of carbon strengthens steel by 770 pounds per square inch when the carbon is determined by combustion. The strengthening effect is 820 pounds for each 0.01 per cent as determined by color.

Phosphorus. — Each 0.01 per cent of phosphorus strengthens steel by 1,000 pounds per square inch.

Manganese. — Each 0.01 per cent of manganese has a strengthening effect upon steel, and the effect is greater as the content of carbon increases. Below a certain content of manganese the effect is complicated by some disturbing condition, probably iron oxide, so that a decrease in manganese in very low carbon steels is accompanied by an increase in strength. In acid steel each increase of 0.01 per cent in manganese above 0.4 per cent raises the strength of acid steel an amount varying from 80 pounds in a metal containing 0.1 per cent carbon to 400 pounds in a metal containing 0.4 per cent carbon. In basic steel each increase above 0.3 per cent raises the strength an amount varying from 130 pounds in a metal containing 0.1 per cent of carbon, to 250 pounds in a metal containing 0.4 per cent of carbon.

Sulphur. — The effect of sulphur on the strength of acid and of basic steel is very small.

Formulas: From the foregoing results, the following

formulas may be written in which C = 0.01 per cent of carbon, P = 0.01 per cent of phosphorus, Mn = 0.01 per cent of manganese, R = a variable to allow for heat treatment, and the answer is the ultimate strength in pounds per square inch. The coefficient of manganese in acid steel, called x, is the value given in a table, and applies only to contents above 0.4 per cent. The value of manganese in basic steel, called y, is the value given in another table, and applies to contents above 0.3 per cent.

Formula for acid steel, carbon by combustion:

$$40{,}000 + 1{,}000\ C + 1{,}000\ P + x\ Mn + R = \text{ultimate strength}$$

Formula for acid steel, carbon by color:

$$39{,}800 + 1{,}140\ C + 1{,}000\ P + x\ Mn + R = \text{ultimate strength}$$

Formula for basic steel, carbon by combustion:

$$41{,}500 + 770\ C + 1{,}000\ P + y\ Mn + R = \text{ultimate strength}$$

Formula for basic steel, carbon by color:

$$42{,}000 + 820\ C + 1{,}000\ P + y\ Mn + R = \text{ultimate strength}$$

No. 243.

Comparison of Methods for the Determination of Carbon and Phosphorus in Steel. Baron H. Jüptner von Jonstorff (Austria), Andrew A. Blair (United States), Gunnar Dillner (Sweden), and J. E. Stead (England). The Iron and Steel Institute, New York meeting, October, 1904. 22,000 w., illustrated. — At the autumn meeting of the Iron and Steel Institute, held in Glasgow in 1901, a committee was appointed, consisting of the authors of the present paper, to further investigate the analytical methods for the determination of carbon and phosphorus in steel.

Conforming to proposals made, homogeneous samples of borings were taken from the lower ends of ingots containing respectively about 0.1 per cent, 0.5 per cent, 1.0 per cent and 1.5 per cent of carbon. Samples of each steel were then distributed to the respective analysts. Each member of the committee was asked to test his samples by his own approved method, and also by the methods employed by the other analysts.

The methods used by each analyst are described at length in the paper.

The following table gives the average of the results ob-

tained by working with the methods approved by each analyst, viz.:

Carbon Determinations

	H. 971 Per Cent	M. 76 Per Cent	H. 739 Per Cent	L. 422 Per Cent
Dillner	1.46 1.45	1.02 1.01	0.45 0.44	0.10 0.10
Jüptner	*a* 1.57 *b* 1.52 *c* 1.439 *d* 1.450	1.105 1.071 1.046 1.068	0.459 0.439 0.424 0.459	0.141 0.0936 0.140 0.142
Blair	1.415 1.412	1.040 1.038	0.434 0.432	0.098 0.097
Stead	1.44 1.40	1.035 1.020	0.420 0.420	0.10 0.096

Phosphorus Determinations

	H. 971 Per Cent	M. 76 Per Cent	H. 739 Per Cent	L. 422 Per Cent
Dillner	0.0225	0.0225	0.0230	0.030
Jüptner	0.0305	0.0320	0.0275	0.027
Blair	0.0190	0.0180	0.0220	0.026
Stead	0.0230	0.0245	0.0245	0.0295

On comparing the above results, it will be seen that the greater part of the determinations agree closely, but there are exceptions to this rule.

With regard to the methods for the determination of carbon, Mr. Dillner and Mr. Stead both agree in strongly recommending the two direct combustion processes. It will, however, be noticed that excepting in high carbon steel the results obtained by the cupric chloride indirect method agree very closely with those obtained by the direct processes.

Theoretically the wet and dry combustion processes should give the most trustworthy results.

With regard to the phosphorus determinations, the results are again somewhat variable.

Mr. Blair's results are generally lower than those obtained by the other analysts. The results of Messrs. Dillner and Stead agree throughout very closely, whereas those obtained by Baron H. von Jüptner are, with one exception, higher than

the others. Theoretically there is no reason why they should not agree. They were all obtained by the molybdate process, Mr. Blair having determined the molybdenum precipitated volumetrically, whilst Baron H. von Jüptner adopted a method which slightly differs from that of Messrs. Dillner and Stead in the system of weighing.

The committee are continuing their investigations, and are endeavoring to ascertain whether or not, hydrocarbon gases do escape when steel is dissolved in cupric potassium chloride and the reasons for the discrepancies shown above, the results of which will be presented on some future occasion. No. 244.

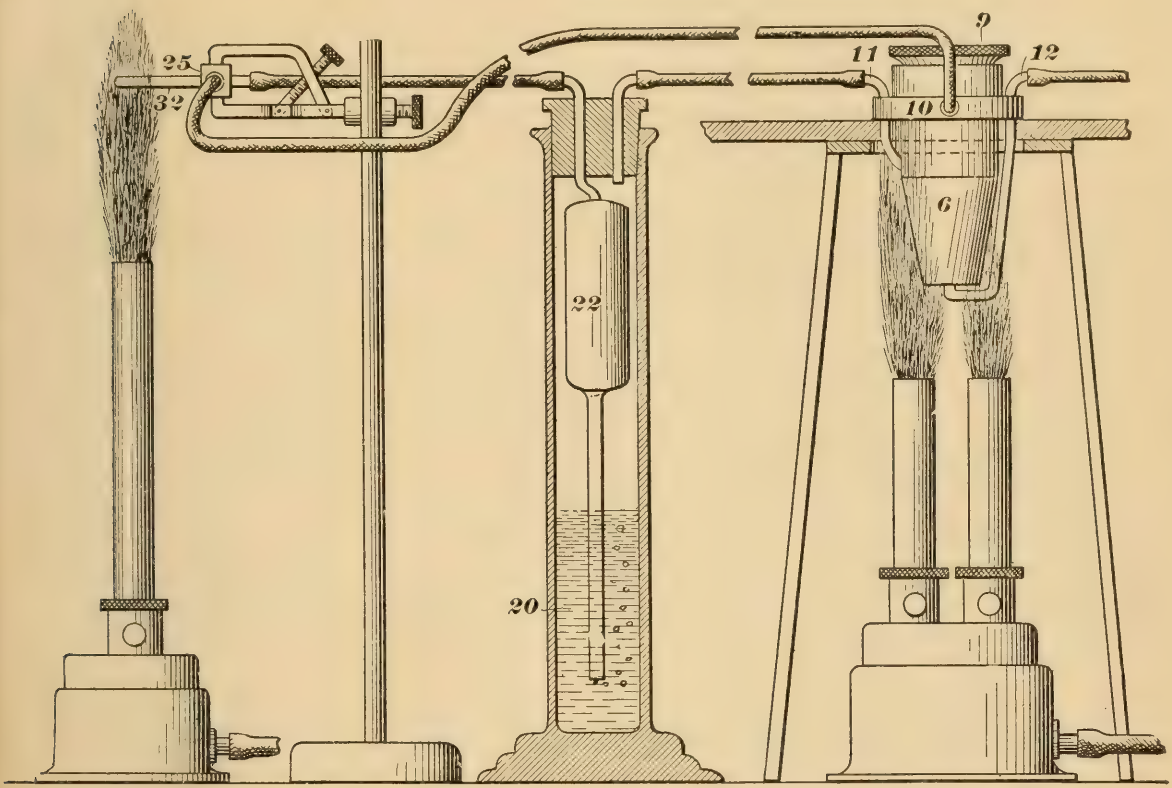
The Determination of Carbon with Special Reference to the Stability of Carbon Compound in Steel. James A. Aupperle. "The Iron Age," October 6, 1904. 2,500 w.

Description of Method. — One gram of high carbon steel is dissolved in 60 cubic centimeters cuprammonic chloride contained in a four-ounce, wide mouth, glass stoppered bottle. Violent agitation usually causes the steel to go into solution in five minutes. After solution the bottle can be placed in a centrifuge and whirled for a minute. The residue settles in a compact mass, and the solution filters very rapidly. A Gooch crucible is used for filtering.

After washing the residue with dilute hydrochloric acid and water, the crucible is heated to 125° for 15 to 30 minutes. It is then placed in the special combustion crucible. The preheater being hot, the crucible is heated to redness, oxygen or air being forced through the apparatus in the meantime at the rate of 100 to 150 cubic centimeters per minute, and same continued for five minutes.

The barium carbonate formed is filtered on a seven centimeter paper, washed with boiled distilled water, burned and weighed. It was found that the oxygen or air could be forced through the apparatus at the maximum rate of 250 cubic centimeters per minute, and three minutes is sufficient to sweep all carbon dioxide into the absorption bulb, and no carbon escaped complete oxidation or passed through 100 cubic centimeters of barium hydrate. If less than 100 cubic centimeters is used, or there is much less than 25 grams barium hydrate

to the liter, then there is loss from some carbon dioxide passing through unabsorbed when using 250 cubic centimeters air per minute. It is also shown that the least amount of air that would oxidize a one per cent carbon and completely sweep it into the barium hydrate was 400 cubic centimeters; 100 to 150 cubic centimeters of air per minute for five minutes has been found to give good results.



Special Form of Apparatus Used.

Description of Apparatus. — The apparatus used in these experiments was designed by the writer and is shown in accompanying engraving. It consists of a platinum crucible, 6, closed by a nickel stopper, 9, carrying a ground joint without washers of any kind. An annular water jacket, 10, surrounds the crucible, through which pass both inlet and exit tubes, 11 and 12. The exit tube 12 is connected directly with a ten-bulb Meyer tube containing 100 cubic centimeters of a 2½ per cent solution of barium hydrate. This exit tube has a bundle of fine platinum wire within it, just below the bottom of the crucible. This wire answers two purposes: First, to absorb

the heat from the bottom of crucible until tube 12 is hot enough to oxidize all carbon monoxide to dioxide, and, second, to assist in oxidation of carbon monoxide.

This apparatus requires no copper oxide, and will do good work without the bundle of platinum wire, but the speed is limited without wire. The inlet tube 11 is connected with a straight tube containing stick caustic potash. This in turn is connected to washing bottle, 20, containing caustic potash. The pipette, 22, prevents any recession of potash into U-tube, 32, should there be any back pressure. The platinum U-tube, 32, surrounded by a water jacket, 25, is heated to redness at the bend, and performs the function of oxidizing to carbon dioxide all carbon compounds likely to contaminate the air or oxygen used for combustion. Some chemists use a cumbersome preheating furnace for this purpose. They will appreciate the advantage of so small and efficient a substitute, termed by the writer a "preheater." The water jacket of the preheater can be connected with the water jacket of the crucible, and one connection serves to connect it with the water service, and another to the drain into the sink.

Walters showed that no copper oxide is necessary when a platinum tube is used. He made a combustion in ten minutes, and suggested that it might be possible to make one in less time. **No. 245. A.**

A West African Smelting House. C. V. Bellamy, with an appendix by F. W. Harbord. The Iron and Steel Institute, New York meeting, October, 1904. 17,000 w., illustrated.—The paper describes a primitive direct method of extracting iron from its ore still in use in the British Colony of Lagos, West Africa. The small cupola furnace used is of the Stückofen or high bloomary type and the metal obtained is a white cast iron partially refined by the oxidizing flux used in smelting. The operation lasts 36 hours, at the end of which a lump of iron weighing some 70 or 80 pounds is extracted from the furnace. **No. 246.**

Shrinkage Troubles and Methods of "Feeding." Thos. D. West. Paper read before the New England Foundrymen's Association, Boston, Mass., October 12, 1904. "The Iron

Trade Review," October 20, 1904. 2,500 w., illustrated. — The author describes the shrinkage of castings as well as the various methods employed to prevent shrinkage evils such as interior rod feeding, exterior rod feeding, statical pressure feeding, shell feeding and compression feeding. **No. 247. A.**

The Utilization of Exhaust Steam, from Engines Acting Intermittently, by Means of Regenerative Steam Accumulators and of Low-Pressure Turbines of the Rateau System. Emile Demenge. The Iron and Steel Institute, New York meeting, October, 1904. 11,000 w. **No. 248.**

Iron and Steel for Western Canada. William Blakemore. "The Engineering and Mining Journal." 1,200 w. — The author asks whether it would not be possible to establish a steel-making industry in British Columbia which would serve the West with appreciably cheaper iron and steel and realize a profit on its product? A critical examination of this question leads him to infer that "the market and the natural resources are ready to the hand and that it only requires capital and brains to convert a great possibility into an assured success." **No. 249. A.**

Hot vs. Cold Galvanizing. Charles F. Burgess. "Lead and Zinc News," September 19, and October 3 and 17. 8,000 w. **No. 250. A.**

The Rolling of Sections of Iron and Steel. Adolph S. White. "The Iron Age," October 13, 20 and 27. 6,000 w., illustrated. **No. 251. B.**

The Iron Ores of Shady Valley, Tennessee. Lynwood Garrison. "The Engineering and Mining Journal," October 13, 1904. 3,000 w. **No. 252. A.**

Ore-Handling Plant at the Clairton Works of the Crucible Steel Co. C. H. Wright. Read before the Civil Engineers' Club of Cleveland, January 12, 1904. "Journal of the Association of Engineering Societies," August, 1904. 5,000 w., illustrated. **No. 253. B.**

Notes on American Steel Works. David E. Roberts. "Engineering," September 9, 16, 23 and 30. 70,000 words.,

illustrated. — A description of the most salient features of American iron and steel mills. **No. 254. B.**

Mining and Metallurgy at the St. Louis Exposition. H. Bauerman. The Iron and Steel Institute, New York meeting, October, 1904. 1,500 w. **No. 255.**

"The Foundry." The November (1904) issue of "The Foundry" contains the following articles of interest:

"Pattern Shop of the B. F. Sturtevant Co., Hyde Park, Mass."

"Mechanically-Made Cores." G. H. Wadsworth. Paper read before the Philadelphia Foundrymen's Association, September, 1904.

"Scrap Iron Specifications." W. G. Scott. American Foundrymen's Convention, June, 1904.

"The Small-Converter Problem." Arthur Simonson.

"Heavy Foundry Work." **No. 256. A.**

Chemistry of Cast Iron. H. E. Field. A paper read before the New England Foundrymen's Association, Boston, November 9, 1904. "The Iron Trade Review." 2,200 w. — An elementary description of some of the influence of impurities in cast iron. **No. 257. A.**

Chemistry in the Foundry. Dr. R. Moldenke. A paper read before the New England Foundrymen's Association, Boston, November 9, 1904. "The Iron Trade Review," November 17, 1904. 1,600 w. — The author deals with the application of chemistry to the economical conduct of foundry operations, and especially to the purchasing of pig iron and coke. **No. 258. A.**

Notes on Southern Pig Iron. Eliot A. Kebler. A paper read before the Pittsburg Foundrymen's Association, Pittsburg, November 7, 1904. "The Iron Age," November 17, 1904. 1,000 w. **No. 259. A.**

Forging Machinery. James H. Baker. A paper read before the Engineers' Society of Western Pennsylvania, November 1, 1904. "The Iron Age," November 17, 1904. 1,600 w. — The author describes briefly forging machinery, as well as heating and welding operations. **No. 260. A.**

BENNETT H. BROUGH

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IRON AND STEEL METALLURGICAL NOTES

Bennett H. Brough. — We reproduce as a frontispiece to the present issue of *The Iron and Steel Magazine* a recent photograph of Mr. Bennett H. Brough, the secretary of the Iron and Steel Institute. Mr. Brough was educated at the Royal School of Mines, London, and at the Royal Prussian Mining Academy at Clausthal in the Hartz Mountains. He was formerly Instructor in Mine Surveying at the Royal School of Mines, and is the author of the standard English treatise on mine-surveying (1st edition 1888, 10th edition 1903). He was appointed co-editor of the "Journal of the Iron and Steel Institute" in 1884, and secretary on February 24, 1903. He is a Knight of the Swedish Order of Wasa, an Associate of the Royal School of Mines, a Fellow of the Geological Society, and a Member of Council of the Institution of Mining Engineers. He has also served on the councils of the Institute of Chemistry and of the Chemical Society. He served as Juror at the Inventions Exhibition in London in 1885 and at the Paris Exhibition of 1900. He received a medal for the collection illustrating the mineral resources of Great Britain, formed by him at the request of the Royal Commission for the Chicago Exposition of 1893. He delivered before the Society of Arts courses of lectures on mine-surveying (1892), on metalliferous deposits (1900) and on non-metallic minerals (1893) which have been published in book form, and he is the author of numerous papers on mining and metallurgy.

The Iron and Steel Institute. — For the second time in its history the Iron and Steel Institute has met in America. The opening session was held in New York, on the evening of October 24, at Sherry's. Addresses of welcome were delivered by C. V. Fornes, acting Mayor of the City of New York; by John Fritz, Bessemer Gold Medallist, and by James Gayley,

First Vice President of the United States Steel Corporation and President of the American Institute of Mining Engineers. The speakers were introduced by C. Kirchhoff, Chairman of the American Executive Committee.

The Bessemer Gold medal was presented in behalf of the Council to Andrew Carnegie, President of the Iron and Steel Institute, by Sir James Kitson, Bart., M. P., past President.

The meeting was followed by a reception and dancing.

Tuesday was given up to an excursion up the Hudson to West Point on the Steamer Monmouth which left at 10.30 a. m. with nearly 700 on board, returning to New York at 6 p. m.

On Wednesday morning the Institute held its first technical meeting at its headquarters, Hotel Astor, when the following papers were read and discussed:

"The Application of Dry-Air Blast to the Manufacture of Iron," by James Gayley, a paper which will be found reproduced in full in the present number of *The Iron and Steel Magazine.*

"The Influence of Carbon, Phosphorus, Manganese and Sulphur on the Tensile Strength of Open-Hearth Steel," by H. H. Campbell.

"Iron and Steel at the St. Louis Exposition," by Professor H. Bauerman.

"A West-African Smelting-House," by C. V. Bellamy.

"A Power Gas Plant for Johannesburg," by P. J. Mullmann.

The second session was held Wednesday afternoon at 2.30, Past-President Windsor Richards, presiding. In the absence of the author, the secretary, Bennett H. Brough, read the following paper which was extensively discussed: "The Development and Use of High-Speed Tool Steel," by J. M. Gledhill. This paper will be reproduced in full in the January issue of *The Iron and Steel Magazine.* The following papers were read by title: "Acid Open-Hearth Manipulations," by Andrew McWilliam and William H. Hatfield (reproduced in full in this issue). "The Utilization of Exhaust Steam from Engines Acting Intermittently by Means of

Regenerative Steam Accumulators and of Low-Pressure Turbines on the Rateau System," by Emile Demenge.

On Wednesday evening the New York meeting was brought to a close with a banquet at the Waldorf-Astoria, over 350 members and friends being present. The following speakers were introduced by President Andrew Carnegie: Sir James Kitson, Charles Kirchhoff, E. Windsor Richards, past President; Rear Admiral Coghlan, United States Navy; Dr. Alexander C. Humphreys, President of the Stevens Institute of Technology; E. P. Martin, past President; Professor Henry M. Howe and Dr. R. W. Raymond, Secretary of the American Institute of Mining Engineers.

The members of the Institute and their friends left New York Thursday morning for an extended tour of the iron and steel works of the United States. Among the works visited we note: The Bethlehem Steel Co., South Bethlehem Pa.; the Maryland Steel Co., Sparrows Point, Md.; the Homestead, Duquesne and Edgar Thompson Works of the Carnegie Steel Co., Pittsburg and vicinity; the Westinghouse works, East Pittsburg; the Newburg works of the American Steel and Wire Co., Newburg, etc.

A party of some ninety members left Pittsburg Friday afternoon, November 4, in a special train for St. Louis and Chicago where the works of the Illinois Steel Co. were visited.

Saturday afternoon, October 29, the members were received by President Roosevelt at the White House, the visitors being introduced by Mr. Carnegie. Most of the members again assembled in New York Tuesday, November 8, some of them sailing the following Wednesday, others the following Saturday.

The Electrical Production of Steel in Sweden. — Those furnaces in which the direct heat of an arc formed between an electrode and the iron in the furnace is employed are handicapped by the fact that the temperature of the arc is in the neighborhood of 3,700° C., which is much more than is necessary to melt steel, consequently the metal close to the arc becomes burnt before that further off is melted. Another type of furnace that has occasionally been tried depends on the heat developed in the steel itself by the passage of a heavy current.

The low resistance of the metal in the molten state, however, necessitates the use of enormous currents with such furnaces, and this leads to trouble at the electrodes and great expense in the copper supply mains. According to "Die Elektrotechnische Rundschau," an improved furnace, depending on the induction principle, has been at work for some time past at Gysinge, in Sweden, with very satisfactory results. The smelting chamber consists of an annular cavity, coated inside with firebrick and closed at the top by lids which are preferably on the floor level. Through the center of this ring one limb of a rectangular transformer core passes, the remainder of the core being completed beyond the ring. The core is, in fact, linked with the annular cavity as one link of a chain is looped with the next. The primary winding of the transformer is placed immediately round that limb of the core which is surrounded by the annular chamber. A single-phase alternating current is passed round this primary winding, and induces a flux in the iron core, which, in turn, sets up a current in the material to be melted, the value of this secondary current depending on its primary voltage and the primary turns. The first of these furnaces was set up in 1900, and produced steel excellent in quality, but at a slow and expensive rate, the output being only 595 pounds of steel in 24 hours, with a power expenditure of 78 kilowatts. A few months later a second improved furnace was erected which gave 1,320 pounds to 1,540 pounds per 24 hours with 58 kilowatts. In 1902 the matter was taken up on an enlarged scale, and has been working satisfactorily ever since. The capacity of the new furnace is 3,960 pounds, and out of this only about 2,200 pounds to 2,420 pounds is drawn off at a time, so that the secondary circuit is never quite broken. The rate of production is 9,050 pounds of steel per 24 hours with a power of 165 kilowatts. The supply is obtained from a 3,000-volt single-phase generator, and the secondary current through the steel is about 30,000 amperes. The steel produced is of exceptionally good quality, and unusually dense and homogeneous. It can be readily worked cold, and is less liable than ordinary steels to spring or become distorted when hardened. "Iron and Steel Trades Journal," October 8, 1904.

Iron Making Along the Upper Lakes. — Iron making along the upper lakes, in close proximity to iron mining, is on the increase, and there has never been as large a product in that district as now, nor one so based on sound plans and so successful. The daily output is now between 900 and 1,000 tons, more than three-fourths of which is charcoal iron. With resumption of blast by several small charcoal furnaces at points in northern Michigan this amount will exceed 1,000 tons.

The only coke furnace in the region is that of the Zenith Furnace Company, at Duluth, which is making 250 tons daily of Bessemer iron. The company is shipping most of its iron to the Sault for steel rail-making. An important feature of this Duluth operation is that an all Mesabi mix is used, reducing the cost of the iron, and that the by-products are saved and utilized to such an extent that the plant would be a large financial success if its pig iron were sold at cost. But it makes about 10,000,000 feet of gas monthly and a very large amount of ammonia and tar. The tar itself is not reduced to its subordinate products.

The Pioneer furnace of the Cleveland Cliffs Iron Company, of Marquette, is now making about 130 gross tons of high-gade charcoal iron daily. From its by-product retorts it is producing, as an adjunct to the manufacture of pig iron, 2,500 gallons daily of 95 per cent refined methyl alcohol, 1,250 pounds of acetate of lime, and some 200 barrels of wood tar. All the fuel for the smelting of ore at the furnace also comes from this by-product plant. The ores used are from the company's own mines at Ishpeming and Negaunee with a little from its Ashland mines at Ironwood.

At the Sault the Lake Superior Company is now blowing in its first furnace, a 150-ton charcoal stack. It has a large by-product plant and is making even more alcohol, etc., than the Marquette company. In order to make a Bessemer product the Sault company buys ore. There is a 125-ton charcoal furnace at Ashland, running on ores owned by the company. This furnace is the only one of its kind in North America, in that the manufacture of iron is incidental to the securing of wood alcohol. It is owned by a varnish-making firm which

uses vast quantities of alcohol, and in order to secure this it operates the Ashland furnace and a smaller one at Manistique. The Sault company now has no competition in Canada, but a 500-ton mill is under way at Sydney, and will be making rails by January 1. "Iron and Machinery World," October 15, 1904.

A New Compound for Making Molybdenum Steel. — At a recent meeting of the Academy of Sciences of France, held at Paris, M. Henri Moissan presented a paper concerning the preparation and characteristics of a new carbon compound containing molybdenum. This compound is obtained by heating charcoal with melted molybdenum and aluminium in an electric furnace. The resultant metallic mass is treated with a concentrated solution of potash, and needles of well-defined crystals of the new carbon compound are obtained.

The substance is very hard, is hardly attacked by acids other than nitric, and is not decomposed by water or steam at a temperature below 600° C. It resembles the carburet of tungsten, already known, which is not considered surprising, as the metals tungsten and molybdenum are much alike. It is thought that this new compound may play a rôle in molybdenum steels.

At the temperature of boiling aluminium a molybdenum compound is obtained which contains twice as much carbon as the compounds formed at the highest heat obtainable in the electric furnace. "Mining Reporter," October 6, 1904.

Domestic Manufacture of Ferro-Phosphorus. — For some time mills making steel sheets and steel plates from basic iron have been using ferro-phosphorus in their open-hearth mixtures, in order to obtain a greater percentage of phosphorus to prevent the sheets sticking together in the rolls. It is customary to use enough of this material to raise the basic steel up to the Bessemer limit in phosphorus. Practically all of it has been imported. It runs from 20 to 25 per cent phosphorus and has been selling at $65 to $70 a ton on a basis of 20 per cent phosphorus, the price, however, graduating on a basis of $3.25 per unit of phosphorus up or down. Recently a furnaceman has experimented in the manufacture of ferro-phosphorus

and has succeeded in making it. The furnace is now being remodeled in preparation for the production of domestic ferro-phosphorus. The market is being canvassed and sales have already been made for October, November and December delivery. Hickman, Williams & Co., of Chicago, Cincinnati, Louisville, Pittsburg and St. Louis, have been appointed agents. "The Iron Trade Review," September 1, 1904.

Steel Rails in Canada. — It was recently announced that the Dominion Government has awarded a second contract for 10,000 tons of steel rails to the Consolidated Lake Superior Company. These are for use on the Intercolonial, whose present requirements are estimated at from 30,000 to 50,000 tons. It is also rumored that the company is busy on a 40,000-ton order from the Canadian Pacific. The prices on these rails are not given, but it may be assumed that they are not far from $35 per ton. They will be made from Mesabi ores. "The Bulletin of the American Iron and Steel Association," November 10, 1904.

REVIEW OF THE IRON AND STEEL MARKET

November has been a very interesting month in the American iron and steel trade. The marked improvement in the trade which was noted in our last report did not come at such a time in the year that great hopes could be entertained for its continuance, yet the movement has grown and assumed more important proportions. There have been advances in prices of a number of leading commodities, and buying has been heavy almost all along the line. It is now regarded as certain that 1905 will be a very satisfactory year, from the standpoint both of tonnage and of prices. Were there no further advances in prices, profits per ton would still be fairly remunerative, while there is no question even in the most conservative circles that tonnage will not only exceed that of this year, but will surpass all previous records.

The advances during November may be summarized as follows: November 1, one point on merchant pipe, or about $2.00 per net ton; November 15, two points on boiler tubes, or about $4.00 per net ton; crude steel, including billets, slabs, blooms and sheet and tin plate bars, $1.50 per gross ton; tin plates, 15 cents per box; black sheets, 10 cents per hundred pounds; galvanized sheets, 15 cents per hundred pounds; November 16, wire products, including plain wire, wire nails and barb wire, 10 cents per hundred pounds. These advances were made in controlled products; in products sold in the open market there have been advances of from $1.50 to $2.50 in pig iron and from $2.00 to $3.00 per net ton in skelp, iron bars and cut nails.

In discussing the ore supply in our last report we expressed the view entertained quite generally at the time that there would be a shortage of ore this winter, preventing some of the furnaces tributary to Lake Superior ores from operating throughout the winter. This view must now be modified, as the movement down the lakes as the season closes has been enormous. Last

year's total movement from the Lake Superior region was 24,-281,595 tons, of which 632,045 was by all-rail routes and the balance was down the lakes. Estimates before the opening of navigation this year ran as low as 13,000,000 to 14,000,000 tons for the season. By September estimates had risen to about 19,000,000 tons, but it is now certain that the year's total will lie between 22,000,000 and 23,000,000 tons. The seasons of 1903 and 1904 have been diametrically opposite in their development. Last year opened very well but slumped sharply at the close. This year opened very poorly, both on account of the poor iron and steel outlook and the great strike which prevented much ore from coming down until the season was quite well advanced, while wonderful strides have been made since September 1. The following table illustrates the sharp change, giving the total shipments from upper lake ports to September 1, the monthly movement in September and October, and the tonnage for the balance of the season. In the case of 1904 the tonnage after November 1 is derived from exact statements of the movement through November 19 and close estimates by the individual shippers for the remainder. The all-rail movement in 1904 is assumed the same as in 1903, which is sufficiently accurate.

Lake Superior Ore Shipments

	1903	1904
To September 1	16,429,854	9,615,996
September	2,946,639	4,034,721
October	3,006,857	4,006,442
Balance of season	1,266,200	4,337,000
Total lake	23,649,550	21,994,159
By all-rail	632,045	632,045
Grand total	24,281,595	22,626,204

It will be seen that on September 1 the movement this year had fallen behind almost seven million tons, while the year will close only a million and a half behind. As the great slump in pig-iron production began just as last season closed, the stocks at the opening of this season plus the new ore brought down should be much more than sufficient to carry the furnaces to the beginning of next season, even though there exists some inequality in the distribution.

There has been a continuance of the heavy demand for wooden, steel underframed and all-steel freight cars, and the builders are assured steady operations for several months. Outside of this, there has been very little further increase in actual ultimate consumption, and the heavy buying movement of the month in wire products, merchant bars, pipe, sheets, tin plates and other lighter lines is simply the expression of greater confidence in the future by buyers. Stocks in dealers' and consumers' hands had reached a very low ebb, and are now being replenished to the normal. This, with the natural demand which will arise in the next four months will certainly keep mills well employed through the first quarter of next year. After that, it is counted upon as certain that the very favorable sentiment which will then have prevailed for six months will actually induce increased consumption, and carry the iron trade through the summer and fall with flying colors.

There has been a very light demand for rails, structural shapes, and plates outside of those required for steel car purposes. It is very significant of the strength of the general market that with little support from these great tonnage producing lines we are making pig iron at the rate of between 17,000,000 and 18,000,000 tons per annum, or close to the average of the calendar years 1902 and 1903, the best on record. It shows how enormously consumption of the lighter lines has increased. In merchant pipe, wire, sheets and tin plates our production in this generally unsatisfactory year will pass all records.

Pig Iron. — A widespread buying movement has advanced all classes and grades of pig iron, until the close of the month finds nearly all furnaces well sold up for this year, fairly well sold through the first quarter of next year, and unwilling to sell for the second quarter on any terms. The buying has been principally by the smaller consumers, who are actually using a little more iron than formerly, expect to require more in the future, and are quite willing to commit themselves for it. The market is naturally resting, at approximately the following figures: F.o.b. western Pennsylvania and valley furnaces: Forge, \$13.50 to \$13.75; No. 2 foundry, \$15.00 to \$16.00; basic, \$14.50 to \$15.00; Bessemer, \$14.75 to \$15.25. Delivered Pittsburg: Forge, \$14.35 to \$14.60; No. 2 foundry, \$15.85 to \$16.35; basic, \$15.35 to \$15.85; Bessemer, \$15.60 to \$16.10. At Philadelphia:

No. 2X foundry, $16.25 to $16.50; standard gray forge, $15.25 to $15.75; basic, $15.00 to $15.25. At Chicago: Northern coke foundry No. 2, $16.00 to $16.25; malleable Bessemer, $16.00 to $16.50; southern coke foundry No. 2, $16.85 to $17.15. F.o.b. Birmingham: No. 2 foundry, $13.00 to $13.50; gray forge, $11.75 to $12.25.

Steel. — In the first half of the month steel producers were refusing to sell at the then official prices, some quoting premiums and others refusing to quote at all. On the 15th a straight advance of $1.50 per ton was agreed upon by the billet association, making prices as follows, f.o.b. Pittsburg, for Bessemer or open-hearth, ordinary carbons: Billets, R × R and larger, slabs and blooms, $21.00; smaller billets and sheet and tin plate bars, long lengths, $23.00; extra for shearing, 50 cents; forging billets, $23.00. The mills will sell only a short distance ahead on billets, while sheet bars are hard to secure for any delivery.

Plates and Shapes. — The general market is quiet, but plate mills are quite busy on material for steel cars. Prices are unchanged at the reduction made officially in September.

Merchant Bars. — There has been heavy buying of merchant steel bars, consumers being now alive to the possibility of an official advance. Common iron bars have been advancing and the market is rather irregular, some producers quoting 1.50 to 1.55 cents, f.o.b. Youngstown, although it is claimed some bars, of perhaps indifferent quality, can be had at 1.40 cents, Youngstown.

Sheets. — On November 16 the leading interest announced an advance, effective the day before, of 10 cents a hundred in black and 15 cents a hundred in galvanized sheets, making the official price, in carload and larger lots, f.o.b. Pittsburg, No. 28 gauge, 2.20 cents for black and 3.25 cents for galvanized. All the regularly operative mills were already sold up for two or three months, and are now not anxious to sell much farther ahead at the advance. Demand has been very good for several months, particularly for electrical sheets, of which the consumption has grown enormously.

Tin Plates. — With the sheet advance an advance was made in tin plates of 15 cents a box, making the official price $3.45 for 100-pound coke bright plates, f.o.b. Pittsburg, common coke ternes being $3.25. The leading interest, which had been for a

couple of months operating considerably less than half its mills, is now starting the idle ones very rapidly, the only delay being in laying down steel. By the middle or latter part of December it is expected this interest will be running every one of its regularly operative tin plate plants, of which it has 19, containing 242 tin mills, with a capacity of easily a quarter million boxes weekly, or 10,000 to 12,000 gross tons. It is booking business through the first quarter, and perhaps farther. The independents have been running fairly well all year, but are now hardly able to accept all the business offered, as they have great difficulty in contracting ahead for their steel.

Scrap. — The market is highly excited. There has been great demand for rolling-mill scrap, while the open-hearth steel works have been endeavoring to conceal their demand, as it is a dealers' market, and the appearance of any demand operates to put up prices sharply. Just now no consumers are bidding more than $14.00 for heavy melting stock, delivered, but it is known that some have paid more. Dealers generally are asking $15.00 delivered.

Coke. — The coke market is quite unsettled, with producers asking upwards of $2.00 for standard Connellsville furnace coke for the first half of next year. Consumers are afraid to take hold, as since the cry of no rain was raised in the coke region additional ovens are being blown in, yet there has been no rain to speak of.

STATISTICS

British Iron and Steel Production. — The returns of the production of iron and steel in the United Kingdom during the first half of 1904 have been collected by the British Iron Trade Association. The total output of the pig iron is shown to have been 4,048,965 tons. This is a decrease of 330,033 tons on the output for the first half of the year 1903, which amounted to a total of 4,378,998 tons, and is a decrease of 47,513 tons on the production of the first half of 1902.

The following table presents the leading details in the different districts for each of the three half-years compared:

Pig Iron

District	1902 Tons	1903 Tons	1904 Tons
Scotland*	456,000	580,000	515,000
Durham	480,457	514,886	520,209
North Yorkshire*	990,082	1,092,077	1,018.270
South Wales	373,278	354,533	353,976
West Cumberland	430,127	398,785	378,083
Lancashire	325,067	351,131	269,805
South Staffordshire	187,366	200,967	192,955
Derbyshire	145,720	162,017	155,800
Notts and Leicester	150,398	136,143	83,336
Northamptonshire	90,905	101,903	110,200
Lincolnshire	152,329	158,719	148,281
North Staffordshire	133,089	123,949	125,585
South and West Yorkshire	131,532	144,981	132,064
Shropshire	20,038	23,643	45,401
North Wales	29,890	35,264	
Totals	4,096,478	4,378,998	4,048,965

The production of Bessemer steel ingots in the United Kingdom for the first half of 1904 was 865,683 tons, which compares

* Partly estimated.

with 911,670 tons in the first half of 1903, and with 888,378 tons in the first half of 1902. The following table shows the leading particulars of the output of Bessemer steel in 1904:

District	1903 Tons	1904 Tons
South Wales	243,723	203,826
Cleveland	181,765	151,791
Sheffield and Leeds	133,676	175,262
Cumberland and Lancashire	267,473	263,658
Staffordshire, etc.	85,033	71,146
Totals	911,670	865,683

The production of steel rails in each district for the first six months of 1904 compares as under with the output for the corresponding six months of 1903 and 1902:

District	1902 Tons	1903 Tons	1904 Tons
South Wales	73,119	120,117	85,093
Cleveland	92,316	104,653	100,613
Sheffield and Leeds	53,000	46,200	105,172
Cumberland and Lancashire	191,985	212,994	232,893
Totals	410,420	483,964	523,771

The output of open-hearth steel ingots in the United Kingdom for the first half of 1904 was 1,670,129 tons, compared with 1,639,239 tons in the same period of 1903, and with 1,710,602 tons in 1902:

District	1902 Tons	1903 Tons	1904 Tons
North-east Coast	435,004	424,214	455,250
Scotland	523,786	521,462	564,707
South and North Wales	424,357	364,907	312,426
Sheffield and Leeds	125,306	136,200	128,120
Lancashire and Cumberland	89,500	89,955	78,333
Staffordshire, Cheshire, etc.	112,649	102,501	131,293
Totals	1,710,602	1,639,239	1,670,129

Iron and Steel in France. — Official figures, recently published, give the production of pig iron in France for the first half of the year as follows, in metric tons:

	1903	1904	Changes
Foundry Iron	270,301	287,423	I. 17,122
Forge and steel pig	1,095,120	1,193,214	I. 98,094
Totals	1,365,421	1,480,637	I. 115,216

The production of wrought, or puddled, iron reported was 318,745 metric tons in 1903, and 279,264 tons in 1904, a decrease of 39,481 tons. The production this year included 17,354 tons of sheets and plates, and 261,910 tons of bars, shapes and miscellaneous products. The production of steel for the half-year was as follows, in metric tons:

	1903	1904	Changes
Steel ingots	942,658	1,042,673	I. 100,015
Rails	118,541	137,619	I. 19,078
Sheets and plates	153,290	149,911	D. 3,379
Structural and merchant steel	394,740	464,120	I. 69,380
Total finished steel ...	666,571	751,650	I. 85,079

The figures for finished steel are not quite complete, some minor products not being reported. The statement includes both Bessemer and open-hearth steel, which are not given separately. — "Engineering and Mining Journal," October 27, 1904.

RECENT PUBLICATIONS

Reinforced Concrete Constructions, by L. J. Mensch. 217 5 × 7½-in. pages; 172 illustrations; paper covers. "Cement and Engineering News." Chicago. 1904. Price, $2. — This timely book will be welcomed by the large and increasing number of engineers, architects and contractors interested in reinforced concrete constructions. The information given in this handbook is drawn largely from the author's own experience as designer, consulting engineer and contractor. He has aimed to treat the subject in plain language, entirely free from higher mathematical calculations. The author concludes as follows his short introduction: "Reinforced concrete construction is at the present time little understood by our most competent engineers and architects, due simply to the absence of suitable literature in the English language on the subject. If this handbook becomes the medium of conveying the desired information to the architects and engineers and thereby promoting the more general use of this new method of construction by the public, the writer's aim will have been accomplished."

Transactions of the American Institute of Mining Engineers. Vol. XXXIV. 1,029 6 × 9-in. pages; numerous illustrations. Published by the Institute. New York. 1904. — This volume contains the Proceedings of the eighty-fourth and eighty-fifth meetings of the Institute held respectively in Albany (February, 1903) and in New York (October, 1903). It includes, with their discussion, the following papers relating to iron and steel: "Note on the Influence of the Rate of Cooling on the Structure of Steel," by Albert Sauveur and H. C. Boynton. "Test of Steel for Electric Conductivity, with Special Reference to Conductor-Rails," by J. A. Capp. "The Determination of Power for Rolling Iron and Steel," by Louis Katona. "The Condition and Action of Carbon in Iron and Steel," by Herbert E. Field. "The Electric Steel Furnace at Gysinge, Sweden," by F. A. Kjellin.

The Ironmonger's Workshop. 362 5 × 7-in. pages; 60 illustrations. Published at the office of "The Ironmonger." London. 1904. — This, as the subtitle tells us, is a "Handbook for Methods and Materials for Manufacturing Ironmongers and Workshop Assistants." The book deals with workshop equipment, workshop materials, workshop methods, special work, workshop arithmetic, workshop organization, and contains besides numerous useful formulas and a glossary. It should prove particularly useful to the men in charge of small jobbing workshops.

Liquid Fuel and Its Combustion, by W. H. Booth. 411 7½ × 10½-in. pages; 125 illustrations. Archibald Constable & Co., Ltd. London. 1903. Price, 24*s.*, net. — Both the author and the publishers are to be congratulated upon the production of so excellent and timely a book. The important subject of the combustion of liquid fuel is treated in this book exhaustively and with much authority. It is divided into 32 chapters and contains ten appendices as well as 59 useful tables. The binding, paper and typography are in every way satisfactory.

Untechnical Addresses on Technical Subjects, by James Douglas. 84 5 × 7½-in. pages. John Wiley and Sons. New York. 1904. Price, $1.00. — The book includes the following three addresses: "The Characteristics and Conditions of the Technical Progress of the Nineteenth Century," "The Development of American Mining and Metallurgy and the Equipments of a Training School," and "Wastes in Mining and Metallurgy." These extremely interesting and suggestive addresses should be widely read by engineers and technical men.

Tropenas Converter Steel Process. 29 pages. Powell & Colné. New York. — A fully illustrated and descriptive pamphlet concerning the Tropenas converter, its installation and management.

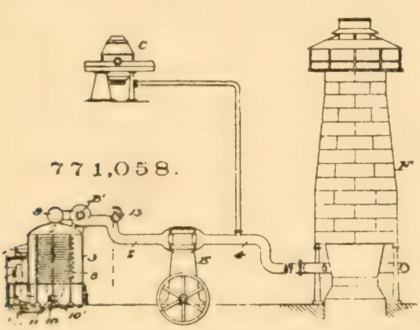
PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

770,910. Cooling Device for Blast-Furnaces. — Ludwig Keyling, Berlin, Germany. In a cooling device for blast-furnaces, the combination of a box, in which the upper opening of the furnace is situated, a plate situated in this box vertically above the upper opening of the furnace, the diameter of this plate being larger than the upper opening of the furnace, so that the edge of this plate projects sidewise over the opening of the furnace, a water-nozzle situated vertically above the plate, an annular channel situated around the top part of the furnace in the box and means for connecting this channel with the outside.

771,058. Method of Extracting Moisture from Air for Blast-Furnaces or Converters. — James Gayley, New York, N. Y. A method of feeding the air blast to blast-furnaces or converters which consists in feeding the air into a refrigerating chamber, distributing it therein in a current directed successively in varying directions, artificially cooling the air in the chamber to reduce its moisture to a small percentage, supplying the dried air to a blowing engine, and feeding the dried air therefrom under compression into the furnace or converter.

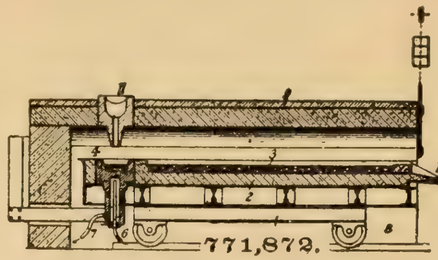


771,220. Apparatus for Treating Iron. — James W. Arnold, Covington, Ky. In a heating furnace, a charging passage, a door normally closing said passage, and adapted to automatically open to deposit the metal delivered thereto upon the hearth, and to again close the passage; and a power-driven carrier adapted to carry and deliver the metal to the charging door.

771,559. Steel Alloys. — Charles E. Manby, Carnegie, Pa. Steel alloys containing nickel and ferro-vanadium, or ferro-manganese.

771,645. Method of Decarburizing Metals or Alloys. — Franz von Kugelgen and George O. Seward, Holcombs Rock, Va., assignors to The Wilson Aluminium Company, New York, N. Y. A process of obtaining metals and alloys low in carbon, which consists in bringing a metal which contains an undesirable percentage of carbon in a molten state into contact with calcium and thereby decarburizing it.

771,872. Furnace for the Manufacture of Steel. — Gustave Gin, Paris, France. A furnace structure, and a hearth inclosed by and movable relatively to said furnace structure, the hearth having two non-carbon electrodes to connect it with a source of electrical energy and having an open channel in which the iron is placed to be treated while at rest, the electrodes being the terminal points of the channel.



771,883. Machinery for Making Seamless Metal Tubes, Etc. — Balfour F. McTear, Rainhill, England. Machinery for manufacturing seamless tubes or hollow bodies, comprising driven parallel cylindrical rollers adapted to hold the billet to be pierced and revolve same; a piercing mandrel at one end of the rollers axially in line with the axis of the billet to be pierced; bearings at each end of the machine adjustable up to and away from the billet-supporting roller, under which said mandrel lies after the piercing action; and a longitudinally-movable stem at the back end of the billet also axially in line with same for supporting back ends of same.

772,164. Process of Dechromizing Iron. — Otto Massenez, Wiesbaden, Germany. A process of dechromizing iron high in chromium, which essentially consists in exposing the metal to an oxidizing-flame in the open-hearth furnace, absorbing the chromic oxide formed by a slag which is easily fusible by itself and proportioning the amount of such slag so that a chromiferous slag containing at most 13 per cent of chromic oxide is formed.

772,354. Electric Furnace. — Henri Harmet, St. Etienne, France. An electric furnace having at its base an enlarged crucible chamber, a series of electrodes penetrating said crucible chamber and forming the poles of an electric current, a discharge from said crucible chamber, means for conveying gas under pressure from the mouth of the furnace into the crucible chamber adjacent to the electrodes, a refining oven and means derived from the electric current for heating said oven, said refining oven arranged adjacent to the discharge of the crucible chamber of the furnace.

772,440. Art of Casting Metals. — Charles S. Székely, Sr., New York, N. Y., assignor, by mesne assignments to The Metal Casting Company of America. Improvement in the art of casting iron and steel in metal molds, which consists in first coating the interior surfaces of the mold with a coating-wash composed of an inert inorganic substance which will have no chemical action on either the metal of the mold or the metal of the casting, and a vehicle of paraffin and kerosene or their equivalents, then closing the mold, and then filling the latter with the molten metal.

772,606. Powdered-Fuel-Feeding Device. — Charles Brossmann, Jr., Indianapolis, Ind. A powdered-fuel-feeding device consisting of a feeding fan with a hollow center having a fuel-feeding aperture associated therewith, a fuel-conveyer apparatus which delivers the fuel in such hollow center opposite the feeding aperture, said aperture arranged for discharging it outwardly to the fan blades.

772,723. Blast-Furnace. — Andrew Latto and James C. Callan, Braddock, Pa. The combination with a blast-furnace, of a conduit communicating with the blast-furnace near the top thereof, and a dust collector composed of a curved elbow, a downwardly-extending tube, angularly-disposed plates arranged in said elbow and having spaces between the plates communicating with the open air.

773,012. Process of Making Steel Wire. — James A. Horton, Providence, R. I., assignor to Iroquois Machine Company, New York, N. Y. An improvement in the art of producing wire by subjecting the same to a plurality of wire-drawing operations in a continuous process, consisting in subjecting the wire to a heat at a drawing station by die action raised to a speed sufficient to heat the wire up to a point overcoming crystalline action, drawing the wire so heated directly into a cooling medium and thereby reducing the temperature to bring the wire to a condition of stability suitable for subjection to a subsequent drawing operation.

773,034. Process of Treating Steel. — Theodore G. Selleck, Chicago, Ill., assignor to Acme Steel Company, Chicago, Ill. A process of converting steel, which comprises surrounding low-carbon steel with a carbonizing compound and packing the charge so formed with a removable package, conveying said package to a converting zone, and then removing the package from the charge contained therein while the charge is in the converting zone.

773,143. Gas Producer. — James A. Herrick, Philadelphia, Pa. In a gas producer, a producer body having a lid comprising a grating and bricks seated in said grating, said bricks extending beyond the inner face of said grating.

GREAT BRITAIN

22,308 of 1903. Heating Blast. — J. Higham, Manchester. Improved means of heating the air supply of melting furnaces, by means of the gases from the furnace.

22,767 of 1903. Open-Hearth Steel Making. — B. Talbot, Leeds. In the duplex system of making steel in the open-hearth process, improvements in the arrangement of the two hearths so that fewer men are required to work them.

16,448 of 1904. Refining Iron. — H. Harmet, St. Etienne, France. Refining cast iron by spraying it through a nozzle with hot-air blasts.

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